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THE MARCH SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

BUILDING A MUSEUM TO HUMAN SPECIFICATIONS. DR. F. C. BROWN 193

INTERNAL SECRETIONS IN EVOLUTION AND REPRODUCTION. DR. OSCAR RIDDLE 202

HOW IT IS DONE BY THE CHEMIST. PROFESSOR D. B. KEYES 217

SCIENCE AND CONDUCT. PROFESSOR A. W. MEYER 222

THE ELEMENTS AND SAFEGUARDS OF SCIENTIFIC THINKING. PROFESSOR ELLIOT R. DOWNING 231

ANIMAL HUSBANDRY AND WAR. SYDNEY HILLYARD 244

JOHN LINING, AN EARLY AMERICAN SCIENTIST. FRANKLIN C. BING 249

A WINTER SLEDGING EXPEDITION ON THE INLAND ICE OF GREENLAND. HELGE BANGSTED 253

CAPTURE OF AN OCEAN SUNFISH. DR. E. W. GUDGER 257

EDWARD EMERSON BARNARD. PROFESSOR ROBERT G. AITKEN 262

THE PROGRESS OF SCENCE:

The Scientific Work of the Secretary of the Smithsonian Institution; Research in Physicis in Yale University; Music from the Ether; The School Service Building of the American Museum of Natural History; The Philadelphia College of Pharmacy and Science 279

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with comments by the publisher

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THE SCIENTIFIC MONTHLY

MARCH, 1928

BUILDING A MUSEUM TO HUMAN SPECIFICATIONS

By Dr. F. C. BROWN

MUSEUMS OF THE PEACEFUL ARTS

BACK as far as 1916 there was recognized such a thing as museum fatigue. B. I. Gilman[1] discussed this subject at some length. He showed a number of pictures in which the visitor was unnecessarily fatigued because things to be seen were displayed in a wrong manner. The pictures showed the visitor in all positions, from standing stretched outright on top of a chair to resting with knees on the floor.

In the same year *The Literary Digest* had an article on treating museum fag.[2] In quoting the New York *Sun*, "The Truth is, very few of us know how to use a museum," and it thinks that there should be schools in which we might learn. "A well known art critic once said that fifteen minutes was as long as any normally constituted intelligence could react on the stimulus furnished by a picture." "Perhaps it would be well to begin the reformatory work with a certain degree of violence. Might not each visitor unable to produce credentials certifying to his capacity to visit the institution, prudently be chained in front of one of the exhibits? Thus he would be compelled to give attention to the treasures brought together for his edification, and restrained from the madness of movement that seizes some people when they pass the portal. In this way, museum fag would be impossible and more of us could enjoy the good things that now so few of us know how to use."

In *The Century*, of January, 1926, F. H. Cooke[3] discusses the subject of "Culture and Fatigue, being some reflections on museums." He says, "Whenever we exhibit things that make for wisdom or beauty, there, I take it, is a museum. It should really be a temple of the muses, but to most of us it is merely an extensive store house where we get tired." He would provide plenty of chairs. "What we most need, however, is occasional ruthless directors who have the strength of mind and skill to weed out all inferior or extraneous matter and box it, burn it or give it away." "It is in fulfilling this function, of giving inspiration for future endeavors, that our museums are apt to fail." "We suffer from the mania of collecting things."

It is obvious, therefore, that museum fatigue is a real and not a fictitious thing. The *Sun* has rather expressed the viewpoint that perhaps folks should be made over, but I am inclined distinctly to the view of Cooke, that the museum should be built to human specification. One museum which can be built to human specification is an indus-

[1] THE SCIENTIFIC MONTHLY, Volume II, pages 62–74, January, 1916.

[2] *The Literary Digest*, 52–1151, 1916.

[3] *The Century*, January, 1926, 111–291.

VISITOR INSPECTING A CROSS-SECTION OF THE ACTION OF A PLAYER PIANO REGISTERING THE INTENSITY OF THE HAMMER BLOW BY DEPRESSION OF THE KEY AT THE RIGHT AND AT THE SAME TIME PRODUCING THE SAME BLOW BY MEANS OF THE PNEUMATIC CONTROL AT THE LEFT

INSPECTING THE INSIDE OF A RIFLE BARREL THROUGH THE MINIATURE PERISCOPE. THE VISITOR OPERATES THIS EXHIBIT BY PRESSING THE PUSH BUTTON WITH HIS LEFT HAND AND EXAMINES THE DIFFERENT SECTIONS OF THE INSIDE OF THE BARREL BY TURNING THE CRANK WITH HIS RIGHT

trial museum. Such an institution can collect and conserve the record of man's industrial accomplishment and at the same time present these records in a manner to stimulate and educate either the layman or the expert.

If a museum is to be built for the lay public, the problem is, to a considerable extent, one for the practical psychologist to solve. Granting that the ultimate purpose of the museum is essentially

LISTENING TO THE MUSIC PRODUCED BY A MODEL OF AN EARLY PHONOGRAPH WHICH IS OPERATED BY THE HAND

educational, we have the same problems that confront an educator who is conducting his work without the moral suasion of grades, prizes, diplomas, and the like.

The first problem, then, of the museum is to gain and maintain its audiences. This means that the visitor should be interested to such an extent that he will desire to return and that he will tell his friends of the profit he has received with a minimum expenditure of energy. After his visit he should not be conscious of severe fatigue to any greater degree

MEASURING IN 1/100,000THS OF AN INCH, BY MEANS OF BANDS OF LIGHT WAVES, THE DEFLECTION OF A STEEL RAIL CAUSED BY THE SLIGHT PRESSURE OF A FINGER ON THE TOP OF THE RAIL

THE COMFORTABLE POSITION OF THE VISITOR WHEN HE VIEWS THE ALPHA RAYS GIVEN OFF BY THE RADIO-ACTIVE ELEMENT POLONIUM

than after a good game of golf, and he should carry away an inspiration and wonder that will strongly impel him to seek further information through means which, in many cases, may be suggested by his visit to the museum.

There are first the purely physical considerations. The temperature and humidity should be as agreeable as possible, and the air and objects should have a minimum of dust and dirt. Wraps

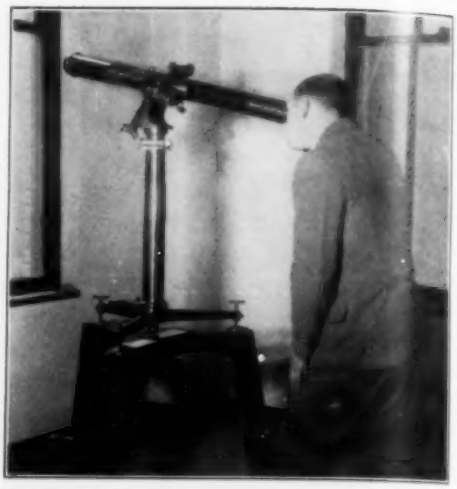
VISITOR INSPECTING THE DAYLIGHT RECORDING APPARATUS WITH THE CHART GIVING THE INTENSITIES OF THE DAYLIGHT FOR EVERY MINUTE OF THE DAY AND COMPARING THIS ILLUMINATION WITH THAT FROM A CONTROLLED SEARCHLIGHT AT THE RIGHT

and packages should be deposited when entering. Much of the walk way surface should be easy on the feet and during the entourage of the museum the visitor should have exercised as many different muscles as he would in his "daily dozen." Chairs and stools should be thoughtfully interspersed throughout the exhibits and provision should be made for accessible dining and luncheing as would enable the hungry visitor to

lengthen his visit and encourage him to make frequent trips to the museum.

The Museums of the Peaceful Arts is conducting a demonstration museum, essentially for invited visitors, in which it is studying the problem preparatory to the establishment of a great industrial museum in the City of New York. With reference to museum fatigue, it has been found that no visitor, even after many hours, has expressed himself as being weary. We may, therefore, call attention to some of the exhibits which seem to the author to be the basis of absence of fatigue.

One of the first exhibits which the visitor sees is from the Research Laboratories of the American Piano Company. He presses one button and hears sketches of music on a player piano. Pressure gages show him the variation of air pressure that produces the varying intensity in the music. When his interest is satisfied on this point he presses the button again, and the music stops. When all the sketches have been played, the music rewinds itself. Before him is a cross section showing how the action in the piano is carried out. He hits the piano key and can see the purpose of the various parts. There is a pointer which registers the intensity with which he hits the piano key, and if he is a musician, he can check his own consistency. Further, by pressing the button, before his eyes he can see how the piano action is carried out by controlled air pressure, and he can set the mechanism on a dial and have the air pressure produce any desired intensity, which, to his surprise, repeats more accurately than he is able to do by striking the piano key.



VISITOR LOOKING THROUGH AN ORIGINAL FRAUNHOFER TELESCOPE

Near by is a model of the first Victrola, upon which the visitor can himself produce music so long as he turns the crank, and he sees there how the governor prevents an excess speed of the turntable when the crank is turned too fast. Following this, he can see and operate the later models of the Victrola.

A few steps away is encased in glass a gun barrel camera, designed and built by the Bureau of Standards. By stooping over and pressing a button with the left hand, the visitor sees the rifling and the erosion of an army rifle barrel. With his right hand he turns a crank which connects inside the case and moves

BY PRESSING THE PUSH BUTTON AT THE LEFT THE VISITOR SEES THE LIGHT BANDS OF INTERFERENCE WHICH MOVE ACROSS A SCALE WHEN THE KNOB AT THE RIGHT IS TURNED, THUS SHOWING HOW ACCURATE MEASUREMENTS ARE MADE

the rifle barrel to different positions, so that he can see any part of the inside just as clearly as if he were to examine the barrel when it is sawed open.

The visitor then turns his eyes to a section of an eighty-pound steel rail, and, without bothering to read labels, he presses a button before him and a mercury vapor light gives its ghastly hue. Beyond this steel rail he observes Newton's rings produced between two optical glass surfaces, and then, noting the pictures and the label before him, he finds that if he will look into an eye-piece on the steel rail, he will there see the light interference fringes, and quite to his consternation, he presses with considerable force on the steel rail and finds that he can bend the rail by seven or eight wave-lengths of light. And like the man who stood in front of the giraffe, he is inclined to say, "There ain't no such animal." But what he usually says is either, "I didn't know that I could bend a steel rail" or "I didn't know that you could measure such small changes by any method." Even the technical student who is familiar with interference rings can study their application to research and industry.

Thus it is to be noted that the visitor, while on his feet, is in various attitudes

THE VISITOR IS FASCINATED AT THE DIFFERENT EXPRESSIONS AN OBJECT TAKES ON UNDER DIFFERENT LIGHTING CONDITIONS PRODUCED BY THE THREE-WAY SWITCH AT THE RIGHT

THE VISITOR HERE IS ABLE TO STUDY THE MOVEMENTS OF ROTATING APPARATUS BY LOOKING THROUGH THE ROTATING SLOTS OF THE STROBOSCOPE AND MAKING THE PROPER ADJUSTMENTS ON THE SLIDING BAR AT THE FRONT

and positions, almost comparable to those in a game of golf. But for fear that he is tired of standing, he notes a telephone booth which is labeled "Radium Exhibit." By reading the label on this booth, he learns that if he will seat himself inside, he may see alpha rays from radium striking upon a zinc sulphide screen, and that further he may press two small keys, not unlike piano keys, and bring either a sheet of writing paper or an extremely thin sheet of mica in the path of these rays. He does this and finds that the sheet of writing paper completely stops the alpha rays, and further, that the mica is so thin that a number of the alpha rays pass right through it.

The visitor then turns to the Daylight Recorder, a joint exhibit of Leeds and Northrup Company and the Case Research Laboratories. He sees on the cross-ruled paper the continuous record of the sunshine on the top of the 17-story building, and on the same sheet, the record of the light intensity in the room. He sees that this double point recorder alternately makes the record of the light variation on the roof and in the room.

CLOSE EXAMINATION OF SMALL ARTICLES FOR THE PURPOSE OF THOROUGH STUDY IS AFFORDED THE INTERESTED VISITOR

BY MEANS OF THIS AUTOMATIC SCREW MACHINE THE VISITOR IS ABLE TO STUDY OUT THE COMPLETE PROCESSES OF MANUFACTURE CARRIED OUT IN THE LARGER MACHINE

He presses the button and increases the light intensity on the Case photo-electric cell in the room, and with his right hand changes the resistance in a rheostat, so as to bring this light intensity to any desired value.

He then may go over to an old Fraunhofer telescope which Fraunhofer made just a few years after he had discovered the lines in the solar spectrum (about 1818). The visitor not only observes the remarkable machine work on the instrument, but he looks through an opening in the window to a neighboring sky-

EXAMINING THE MOVEMENTS OF THE ORIGINAL ELI WHITNEY MILLING MACHINE

scraper. As a layman, he may be surprised to find the object which he views upside down.

The visitor now may go to an exhibit showing the relationship between a dial gage with divisions one ten-thousandth of an inch apart to light interference fringes. Using his left hand and looking into the interferometer, he sees the fringes. With his left hand he moves the dial gage and counts the number of fringes that pass by. Thus he obtains for himself an accurate knowledge of the wave-length of light.

Not far away is a simple stroboscope, where the visitor presses a button and can make the blades of an electric fan apparently go forward, backward or stand still, at will. Thus he gains information to explain why the wheels of an automobile, as seen at the "movie," sometimes seem to be revolving backwards, while the machine is obviously going forward.

It is possible to make many studies of illumination by what some have called the "cafeteria" method. The visitor may wiggle a button in different positions and find that the plaster cast looks entirely different, depending upon the direction from which the illumination comes. This is merely one of many similar exhibits from the Engineering Department of the National Lamp Works.

At one end of the museum is an old key suspended by a string leading up to a kite in a make-believe clouded sky. There is a picture of Benjamin Franklin and a framed statement telling of his experiment "drawing lightning from the clouds." The visitor is led to wonder and to read; bringing his hand near the key, he receives a spark of lightning. His imagination comes into play automatically.

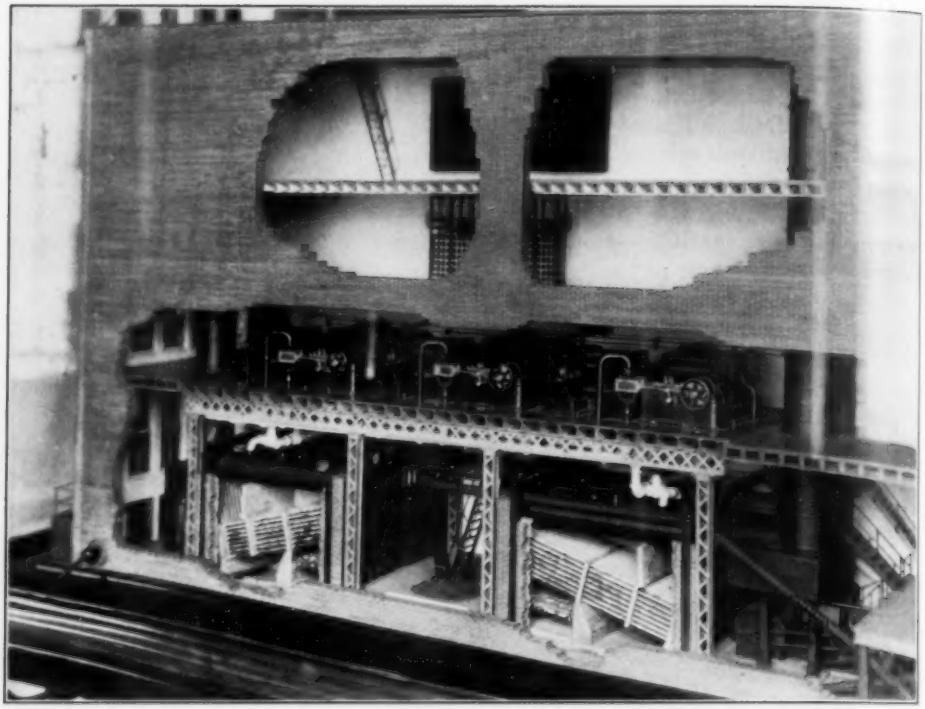
STUDENT TAKING LIGHTNING FROM THE CLOUDS

A somewhat different character of exhibit is Eli Whitney's old milling machine, which is believed to be the oldest in the world. In spite of its age, the visitor can put his hands at various places and gain information as to how this machine once worked. Also, he can turn the crank on the model of the first automatic screw machine which the Brown & Sharpe Company produced. Unless he is familiar with such machines, this is likely to bring his imagination into play as well as his right arm.

Quite another type of exhibit is the model of the world's first electric power distribution station, namely the Pearl Street Station. Here the visitor merely looks, and since he has been participating in so many exhibits, interest alone holds his attention.

There is an old Hall typewriter which the visitor may operate in order to see in what ways it functions differently from the most modern typewriter.

THE VISITOR IS ENABLED TO TYPEWRITE SHORT MESSAGES TO FRIENDS IN OTHER CITIES ON ONE OF THE ORIGINAL HALL TYPEWRITERS



MODEL SHOWING IN COMPLETE DETAIL THE EQUIPMENT USED IN THE FIRST ELECTRIC POWER PLANT IN NEW YORK CITY

Still a different type of exhibit that is common in the museum is that which the visitor can pick up and turn over without doing damage. For example, he may pick up and closely inspect a complicated work-holding device, such as is shown in the picture.

A point that is common in this exhibit as well as in the great preponderance of exhibits in the Museum, is visitor participation. It is somewhat like the old lady who reported that it was a very fine prayer meeting because she took part in it herself. The visitor in such a museum as we are describing should be fatigued to a minimum extent, because of the variety of muscles that are brought into play and because throughout he is conscious of his own participation.

The old saying that you can catch more flies with sugar than with vinegar is applicable to any museum that measures its success in terms of number of visitors multiplied by the degree of interest aroused. The fly is neither attracted nor held to sugar by its color or its shape. The museum visitors are not flies; nevertheless, it takes more than proper beauty and magnitude to attract and capture large numbers of our population.

The exhibits must have fundamental interest. It may be a debatable question whether any museum of science and industry can effectively arouse as great an interest as a prize fight or a football game. Personally, I believe it is possible.

Once an appeal has been established, the visitor's interest will follow a certain amount of tedious, difficult and uninviting exhibits, charts and reading matter, without great fatigue. Unrelieved wis-

dom may bore one, but a wise man may be worthwhile at a dinner party, providing there are also charming personalities and appetizing food. A museum should maintain itself on a lofty plain, but we should compromise with human nature to interest visitors in what we know is worth while. An industrial museum can succeed only in proportion to the visitors it interests. Thousands annually travel more than hundreds of miles to visit the Deutsches Museum at Munich; it is nevertheless of great advantage to have the museum accessible. Millions should be able to reach it within a half hour's journey. The visitor, having arrived at the museum, should find the building without difficulty, and its appearance should make his heart beat faster, much in the same manner as when, in his boyhood days, he arrived near the old swimming hole.

I do not in any way minimize the importance of the great museums that have been built, and it is not our idea that an industrial museum should be a gymnasium or a variety show. But, with the help of the psychologist and the teacher, it is hoped that an institution can be built which will both attract and educate. Well chosen exhibits will make the path of knowledge easier and more attractive both to the research worker and the layman. Special exhibits may be available to the research worker alone.

In speaking of industrial museums, Professor D. C. Miller said in part: "It seems to me that a museum like the Deutsches Museum will do more to develop technical and elementary scientific education than can ever be accomplished in the technical schools and universities. It would do more to educate the common people, ordinary inventors, etc."

The industrial museum should be the embodiment not only of the material forces that have characterized the last century, but should show the upward climb from first beginnings to the present day. It should treat the visitor on the basis of his integrated ancestral experience of hundreds of centuries.

INTERNAL SECRETIONS IN EVOLUTION AND REPRODUCTION[1]

By Dr. OSCAR RIDDLE

CARNEGIE INSTITUTION OF WASHINGTON

THOSE who attend lectures on scientific subjects are, in these days, especially captivated by the revelations of the physicist and the astronomer. Such interest is of course a well-deserved tribute to those who have taken the atom apart, permitting us a charmed look at its pieces; and a tribute to those others who have presented us with a quite new and gripping conception of the extent and structure of the universe. You have doubtless come under the spell of these bold, clear, new truths concerning the infinitely small and the infinitely large; and I must half suspect that many of you are even now thinking of atoms or of stars. To get your consideration of the subject of this hour it is therefore probably necessary, first of all, for me to locate properly in time, space and mass the type of objects which we here purpose to discuss.

From stars or atoms we must make the long journey to the *living* world; and, in the matter of size or mass, the distance—to an animal of the weight of man—is about equally long if we start from the atom or from the star. An eminent British astronomer has calculated that the number of atoms in the body of a man is represented by 10 to the 27th power, while the number of men required to equal the weight of a star is found by taking 10 to the 28th power. How natural, then, is man's pride concerning his position in the universe!

In getting our subject located in duration, or in time, we apparently have to concede that our living world is much *younger* than either atoms or stars. But we can be fairly certain that two of the processes with which we are now concerned—organic evolution and reproduction—are as old as the oldest organisms; also, that sexuality is somewhat less old, possibly spanning not more than half the years between the present and the first living matter on the earth; and finally, that the internal secretions are among the most recent acquisitions of even the higher animals. So recent are some of these secretions—which also pass under the names of hormones and endocrines—that our closest cousins, the mammals, may be said to have invented one or two; and those superior animals which are provided with backbones have probably originated much more than a majority of all the true hormones now known.

If these words carry some indication of the size and time relations of our general subject, it still remains to delimit its relations in space; for, here again we apparently need to concede important limitations. Life is known to exist only at points very near the *surface* of our own planet. If it exists in other worlds it seems likely to be limited to similar surfaces there, unless indeed in those other worlds living matter has developed with quite different properties and relationships than any types of life known to exist on our planet.

Compared with that of the physicist and the astronomer how very minute and limited is this stage on which our material is found! The atom the physicist can get from all depths and heights of our planet, and from any part of the chance meteor that comes to earth from

[1] A lecture delivered at the Carnegie Institution of Washington on the evening of November 15, 1927.

anywhere in space; and, atoms of the same kind behave alike, irrespective of the source of the electrons that enter into them. Another star, or even a new galaxy or universe, the astronomer readily gets by an improvement in his search in most any direction. Again, a beam of light that may have started on its way to the earth millions of years ago supplies much of the standard material now studied by both the physicist and the astronomer. The effort of each of those workers has proved most helpful in solving the problems of the other, and those among them who study the hot stars have even the crowning good fortune of finding matter in its simplest state—gases made up of atoms and broken atoms, atoms stripped of electrons.

With the help of these contrasts let us try to grasp the difficulties of him who would study the performances of matter in the living world, a world built of units always enormously large and complex as compared with the atom. Here is the great chaos of giant molecules—of orderly aggregations continuously displaying the new and difficult properties of living matter—in which the biologist and chemist grope as best they can. Living matter always exists and carries on at low temperatures, and it is precisely at low temperatures that matter exhibits its more troublesome properties.

Perhaps then these few remarks may help you to refocus your lenses, and to warn you that in leaving star and atom for a living thing you have left utterly all there is of simplicity behind. During this hour, at least, we ask you to share the view that it is not an atom, not a stone, not an earth, not a star, not a universe, but a higher animal that embraces the sum of all complexities. If we succeed here in saying things that are simple enough, this must rest on the circumstance that we persistently speak of fragments—not of the whole—of an organism.

In the investigation of any process that occurs in living things we begin by following up the clues that have been provided by previous study. Despite the complexity of our living world the pioneering work of others has already provided some clues—and usually a few tools and methods—for the further examination of most conceivable subjects. Such clues were at hand for a study of a part of our present subject, namely, the problem of sexuality, or sexual reproduction. By chance, these suggestive leads had been found in the bird world—in doves and pigeons—and it thus happens that my studies and questions have been addressed chiefly to the tissues of these particular animals. It seems best here to discuss the various parts of our present subject in essentially the same order in which they were investigated. The original problem with us was to learn the chemical and biological nature of sex-difference. We shall see that problems concerning reproduction and the internal secretions arose at once, and that some aspects of the most fascinating of all problems, namely, organic evolution, have already crept into the unfinished study.

When either the trained biologist or the layman accomplishes a detached view of the human species as an animal species, his first reaction is perhaps that of self-congratulation at its complexity, and at its finish of structure, power and adjustment. His second thought will surely be caught and fixed upon the fact that the individuals of his species are divided, both in form and in function, into two distinct groups. In other words, he becomes conscious of an ever-present and far-reaching divergence of the sexes. When his attention is directed to any other of the thousands of species —any except the lowliest of living things —this second impression dealing with sex-difference will remain; and further reflection upon this fact will bring conviction that sex and sexual reproduction have long had very firm footing in the evolutional marches which led to the origin and survival of the animal world as it now exists.

From these and from other considerations the problem of the nature of the forces which give origin and direction to this nearly universal formation of the two sexes within each species is somewhat akin to the problem of the origin of species. Apart from occupying a nearly central place in biological theory, sexuality stands a problem of great interest and importance to most branches of knowledge and to quite all of mankind.

The further development of our subject requires the use of a number of illustrations. Fig. 1 will help to make clear the nature of the two clues which supplied a beginning for our studies. Whitman had observed that when doves or pigeons are induced throughout the year to lay large numbers of eggs, instead of their usual numbers, the normal proportion of the sexes does not remain constant. Equal numbers or an excess of males are produced from the eggs laid in the earlier part of the season—in winter and spring; but an excess of females arise from the eggs laid in summer or during the later part of the season. In our illustration a pairing of the eggs is indicated by a spacing of the circles which are used to represent the egg-yolks—or, as we can better call them, the ova. The seasonal change of size of the circles is also utilized to indicate the

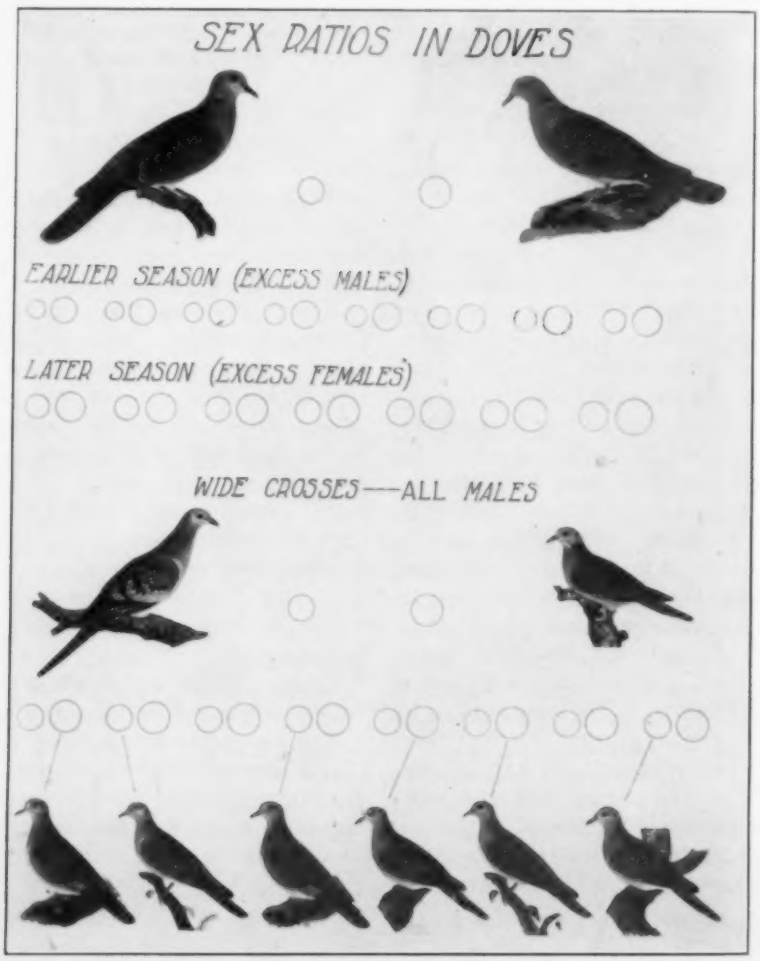


FIG. 1

first facts which we learned concerning the relation of yolk-size to the sex of the offspring. Those ova which are produced later in the season, and from which an excess of females develop, are in general larger than the eggs of late winter or spring which produce an excess of males. Our diagram considerably magnifies the differences actually found, but we are here content to have you observe that the ova increase in size from late winter to early autumn. Weights obtained on more than 20,000 ova have shown that this is the true relationship of season to yolk-size. Of course, size alone, without a knowledge of the chemical composition, is of rather uncertain meaning; but the clue provided by the seasonal change in sex ratio gave us an opportunity to take ova from all seasons of the year for chemical analysis. At the beginning we supposed that a chemical examination of these ova was all that we should do in connection with this subject.

The second clue provided by earlier work can be understood by reference to the lower part of this same diagram (Fig. 1). It had been observed that pigeons belonging to very different species, indeed to different zoological families, are partially fertile; that is, a part of the total number of eggs produced in the widest crosses are fertilized and develop. Here, however, one met the remarkable fact that all the offspring from these widest crosses are males; no females appear among the offspring of two parents which belong to two different zoological families.

Now the special interest attaching to this result lay in the circumstance that birds were known to produce two kinds of eggs, each kind being provided with the chromosomes or hereditary factors normally necessary to give rise to a male in one case, and to a female in the other. In mammals, including man, two kinds of sperm not two kinds of eggs are formed. Since two kinds of eggs are produced by birds, and yet males only result from wide crosses in pigeons, it seemed possible with the help of such crosses to test whether only male-producing eggs are fertilized and develop. Or whether, indeed, the then seemingly impossible thing happened, namely, that some eggs with chromosomes for femaleness are fertilized, but under these unusual conditions are forced to develop into individuals of the opposite or male sex.

Because of the circumstance that in most matings of such dissimilar birds only a few of the eggs laid are fertilized at all, it could be assumed that only male-producing eggs are fertilized. But even the then available facts did not well fit this view. On the diagram we indicate the result of our investigation of this topic. The males forming the row at the bottom are united by connecting lines to both types of ova; the large and the small, the male-producing and the female-producing. Unfortunately, time limits, and the main purpose of this address, will not here permit any real examination of the evidence for this conclusion.

From our point of view, both of these clues indicated that sexuality could here be investigated by chemical means; for, in these animals, it was the ova, not the microscopic sperm, that were sexually different; and a single ovum of a dove or pigeon is large enough to permit an adequate chemical examination. Particularly, the chemical differences which might appear between the eggs produced in early and late season should indicate the nature of the factors, other than genetic or hereditary factors, which underlie the development of the two sexes in these two particular conditions where the normal chromosomal control of sex development clearly fails, or is forced to new and unusual behavior.

It so happened that I was compelled to conduct not only chemical studies on these ova, but to carry on breeding experiments as well. Our procedure involved taking a portion of the eggs

produced by a bird at each of the several seasons for chemical examination; another portion for burning in a machine called a calorimeter; and to have the remaining eggs reared by a reserve battalion of foster-parents—some hundreds of doves kept solely for this purpose—so as to learn the sex which would result from these remaining eggs. The curves or polygons shown in Fig. 2 tell us, for

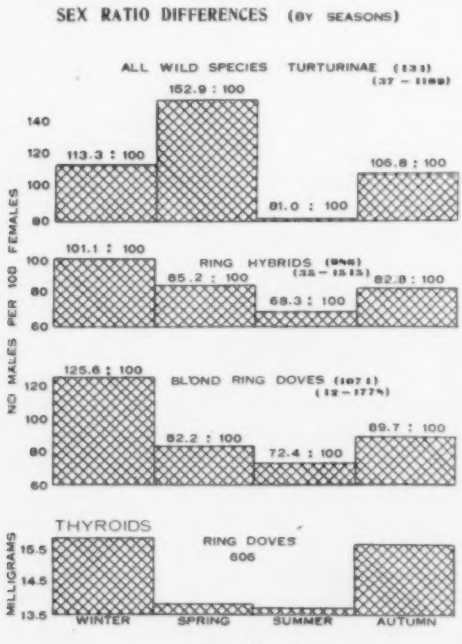


FIG. 2

the three largest groups studied, in what proportion the two sexes were obtained at the various seasons.

In beginning an examination of these polygons it is necessary to know how to define a season for our present purpose, and a momentary digression will permit us to explain how this has been done. Possibly the astronomer's calendar is not that of the pigeon; perhaps the dove has not sensed the equinox and the inclination of the earth's axis. After our results had indicated that the sex of the offspring is related to the rate of metabolism—*i.e.*, to the rate of burning and energy release within the ova—it was plain that the right calendar to use in classifying all our data would be the "metabolic calendar" of the pigeon itself. In order to construct such a calendar for our animals we turned to their thyroid glands; for, in all warm blooded animals, these glands prepare and release an internal secretion which in large measure determines the rate at which they burn food and release heat. It was found that the thyroids of these animals enlarge during October, November and December, and perhaps attain even still larger size during January, February and March. This six-months' period, divided into halves, thus gives us the pigeon's autumn and winter. During the remaining six months the thyroids were found to be consistently smaller, and their structure indicated that they were also less active. These months, likewise divided into halves, give us the pigeon's spring and summer, which extends from the end of March to the end of September. Thus, after all, you see that the dove and his thyroid have been found to record with fair accuracy the position of the earth in its orbit round the sun.

In viewing Fig. 2 and the next following illustrations you are asked to note that seasonal differences, not the full values, are expressed on these polygons. The thyroids were largest in winter, smallest in summer. The sex of the offspring hatched within periods thus defined are shown here. The largest proportion of males is found in the winter or early spring when, for every hundred females, we obtained such numbers as 125 males, 101, 113 and 153 males. On the other hand, in every case the summer brought the greatest excess of females. For each hundred females there were in the various series only 72, 68 or 81 males. During the autumn period the parent birds could no longer be forced to rapid ovulations at a time when their thyroids were enlarging, so that during this period the sex ratio again approaches 100 males to 100 females.

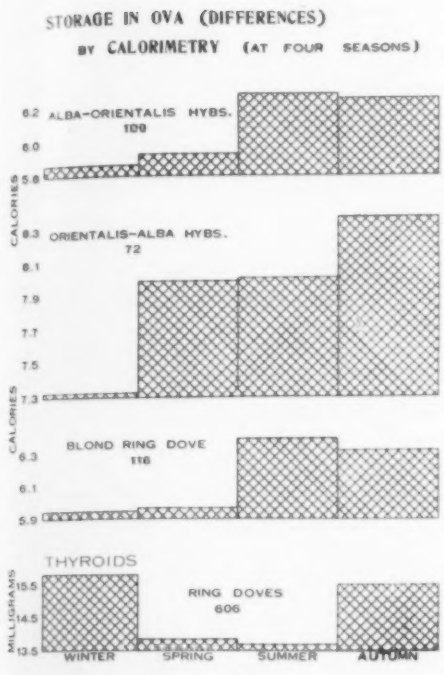


FIG. 3

In Fig. 3 are shown measurements of the amount of energy that was stored in ova produced during the four seasons. Individual yolks were burned in a bomb-calorimeter—an apparatus that accurately measures energy released in the form of heat. The seasonal average of some hundreds of such single determinations are plotted on these polygons. It is plain that least material is stored in the winter and spring—the period of excess male production. Most energy is stored in the summer or early autumn, the time during which the greatest excess of females is produced. Here I think we obtain decisive evidence that the eggs of winter and early spring which yield an excess of males are eggs which store less material than do the eggs of summer and early autumn which give rise to an excess of females.

It is now necessary to understand that a low storage value in a cell means a high burning capacity—a high metabolism—since the living cell can do only two things with food material that it takes into itself. Such a cell can either burn this material or store it. In case the material is burned the products of burning are liquids or gases (CO_2, water, uric acid) and these escape from the cell without increasing its bulk. In case the material is stored it does increase the mass or size of the cell.

It is evident then that the following out of one of our clues has at least partly resolved the problem of sex difference into the problem of metabolic difference.

In our chemical analyses of the dove's ova several different chemical substances were separated in each analysis. We shall here consider only one of these substances. In the polygons of Fig. 4 we have plotted the average percentage of fat in ova obtained at the various seasons. The point of interest here is that the maximum percentage of fat is attained in the summer or in the early autumn, and this coincides with the period of greatest excess of female production. The ova which most often develop into females are ova in which the relative proportion of fat is notably high. This result is an excellent confirmation of what we observed in the immediately preceding figure; namely, that greatest storage of energy was obtained during summer or early autumn, and that the season of greatest storage is the season of least burning. We can say, therefore, that the results of our 1,200 chemical analyses agree well with the results obtained from some 500 direct determinations of stored energy made in the calorimeter. Both of these results indicate that, in our animals, males arise from ova with higher, females from ova with lower, metabolic rate.

The several facts thus far observed on ring doves have been brought together in Fig. 5. The percentage of females is highest where the storage power is greatest; the proportion of females is

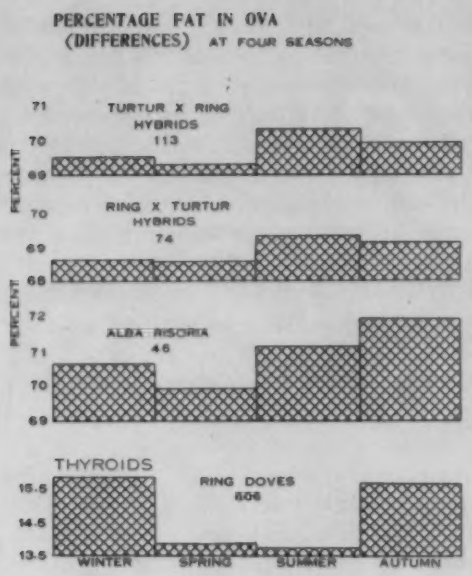


FIG. 4

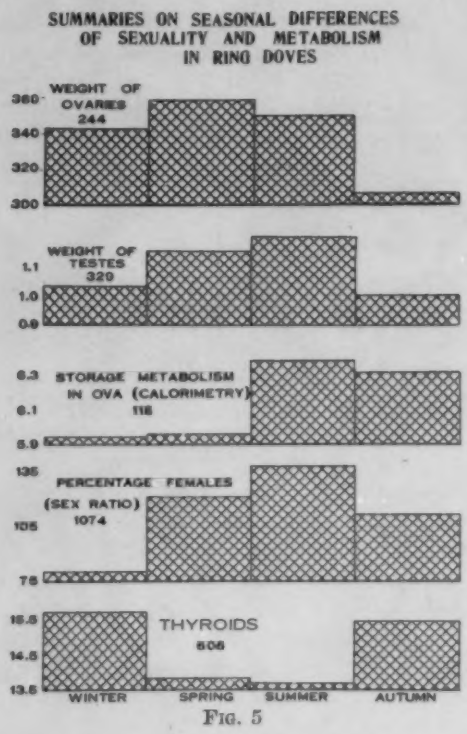


FIG. 5

lowest where the storage power is lowest. Incidentally, it can be observed that the germ glands, testes and ovaries, of these animals undergo a change in size which is quite the reverse of that undergone in the thyroids of these same animals. We thus observe that not only do ova, and the prospective sexuality of these ova, find themselves fluctuating with metabolic changes in the body—as this is indicated by changes in thyroid size—but also the remaining tissues of the germ glands undergo size changes which are comparable in nature. The seasonal changes in sex ratios, which we set out to follow, have now led us into a region of metabolic differences—a region known to be dominated largely by the internal secretions.

Having satisfied ourselves that metabolic distinctions are at the basis of sex-difference in the egg-stage of organisms we wished to know whether these same distinctions persist during embryonic life. In Table 1 you may see the result of our effort to get from dove embryos an answer to this question. We must first state the reason for using this particular method of measurement. The indefinite constantly-changing size of these embryos makes it impossible to measure their metabolism directly. But if male embryos are using oxygen faster than are female embryos, then male embryos should be less injured by abnormally high concentrations of oxygen and more injured by abnormally low concentrations of oxygen than are female embryos. We, therefore, took all of the embryos, that is, all of the fertile eggs, which were produced by our birds during one year and made them undergo from one to five days of their development in atmospheres prepared by us; one series of these atmospheres contained very much oxygen, the other series only about half that of ordinary air.

In these tests a somewhat smaller percentage of males than of females was killed by treatment with "increased oxygen"; and a slightly higher percentage of males survived the "increased oxygen." Further under "decreased

TABLE 1

RESULTS OF SUBJECTING MALE AND FEMALE EMBRYOS TO ALTERED OXYGEN PRESSURES AND LOW TEMPERATURES

NATURE OF TREATMENT	NUMBER OF EMBRYOS	SEXES			
		% KILLED		% SURVIVED	
		♂	♀	♂	♀
COMPLETE DATA					
INCREASED OXYGEN	660	5.6	6.3	94.4	93.7
DECREASED OXYGEN	792	12.2	9.7	84.8	90.3
LOW TEMPERATURE	440	26.3	15.7	73.7	84.3
EXPERIMENTS SHOWING "SEXED" INDIVIDUALS KILLED					
INCREASED OXYGEN	430	13.0	13.1	87.0	86.9
DECREASED OXYGEN	448	29.1	16.8	70.9	83.2
LOW TEMPERATURE	334	33.0	22.3	67.0	77.7

pressures of oxygen" a higher percentage of males than of females was killed; and under "decreased pressures of oxygen" a smaller percentage of males survived. Likewise, low temperatures might be expected to affect sexuality in the same way as does "decreased oxygen." This also proved to be the case. Parts of the same data, taken on a specially rigorous basis, are separately shown on the lower portion of the table. The results there are quite the same. The numbers involved in these experiments are not as large as is desirable; but in this partial test of the question the evidence indicates that the male embryos of doves and pigeons have the higher, female embryos the lower, metabolic rate.

It has recently been shown that very young birds, taken soon after hatching, can still be made to reverse their sex by a single simple surgical operation. This work has been most adequately carried out on young chicks, and by others than myself, though we are also making such operations on young doves. This important result was first obtained four years ago by a French observer who removed the left germ gland—the left ovary—from young chicks soon after hatching. The operated birds were allowed to grow and mature, and it was then found that the right ovary (which is nearly always rudimentary in birds and usually completely degenerates soon after hatching), had here, in each case, continued its growth. Surprisingly enough, in these cases its growth had been continued wholly in the direction of a male germ gland, and indeed a testis which produced sperm was formed. Often, too, on the site of the removed left ovary a second male gland develops.

In these operated animals it was also plain that the internal secretion or hormone of the gland was now that of the male, not that of the female. The comb, plumage and other sex distinctions were now essentially those of a rooster, not those of a hen. Similar results have now been obtained by several workers in various countries and the results are well established. Young birds thus operated usually undergo complete sex-reversal and develop into male adults.

We have very briefly reviewed some of the results which—if they could be completely given—clearly indicate that in the egg-stage, and in early post-embryonic stages, the sex of birds may be reversed. If time permitted two cases of sex-reversal in adult birds could be described.

We have now indicated that during the egg-stage and the embryonic stage, the sexes differ in their rate of metabolism. Naturally, we wish to know whether similar metabolic differences are found in the adult pigeon. This question, among others, is now being studied in our laboratory in collaboration with Professor Benedict, of the Nutrition Laboratory of the Carnegie Institution. At the moment, however, we do not feel prepared to answer this question. Meanwhile, such suitable measurements as are available for the adult human male and female, and for one or two other species of animals, do indicate that the males in these species have the higher metabolism, the difference, in the case of the human, being about 6 per cent. The data at hand seem to warrant the conclusion that males in all life stages have a higher rate of heat production,

energy exchange, or basal metabolism, than have the females of the same species. If this conclusion is supported by further measurements it would seem to be of real importance and of wide application in man's own world. Metabolism in the human is fairly easily influenced by such conditions as habits, diet, occupation and disease; and since sexuality is not an entirely fixed and static thing these metabolic changes are of first importance to the maintenance of normal sexuality. There are several obvious medical and sociological applications of our identification of the relationship of metabolic rate and sex.

Our collaborative study with Dr. Benedict has, however, already made it clear that the rate of heat production is notably affected by both the age of the bird and the amount of space in which it is permitted to live. On the latter point we made 60 measurements on 15 doves with the result shown in the uppermost polygons of Fig. 6. You will see that after males have been confined during several weeks in a space too small to permit flight, their metabolism is at a low level. That following four to five weeks of residence in larger cages, which did permit flying, their metabolism was markedly increased. Likewise, the adult females have a lower metabolic rate when under close confinement, and like their male mates they attained a higher rate in the larger cages. But we call your attention particularly to our finding that close confinement, which we must regard as abnormal, affects the metabolism of the male more severely than that of the female. He loses 19.6 per cent. of his normal rate; she loses only 8 per cent. under the same conditions. If this result holds, and can be extended to other species, we shall here have the real reason why Jack builds a house, but remains in it *less*—and *less* agreeably—than does Jane or Jill.

The lower two rows of polygons show two things. First, that young birds of

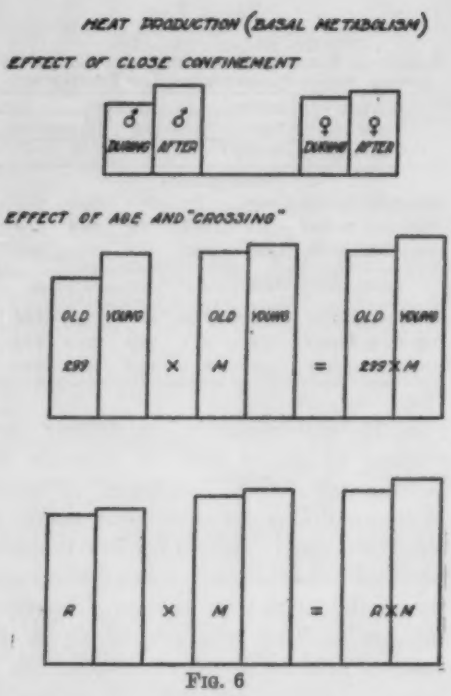


FIG. 6

various races of pigeons have a higher metabolism than do the adults of the same races. This difference is so considerable that the age factor here enters largely into the determination of all questions of sex difference or racial difference in metabolic rate. The second and doubtless more important thing shown by these data must next be noted. These polygons contain, so far as I am aware, the first direct and comparable measurements obtained on the metabolic changes which accompany hybridization —or the crossing of races. Note that the measurements made on the two races of the middle polygon indicate that one race has a lower, the other a higher, metabolic rate; but do not fail to observe that in a cross of these two races the resulting offspring have a higher metabolism than that of the higher race entering into the cross. This result applies to both the young and adult hybrids. Also, the two races whose measurements are placed in the lowest row of polygons have unequal metabolic rates; and again,

the hybrids resulting from a cross of these two races have, in both young and adult stages, a higher metabolic rate than that of the higher race entering into their parentage. These four tests doubtless do not provide an adequate basis for saying that this is a universal principle; but these are the first four tests made, and at present our only completed tests of this subject.

These four tests admirably support the view, first derived from entirely different sources, that a wide cross is in itself a means of raising the metabolic rate in all stages of the developing egg and embryo; and that, because the widest crosses raise the metabolic rate most markedly, such fertilizations result in the production of males, and of males only. We are here at the threshold of identifying the long-known increased vigor of hybrids with increased metabolic rate; and since hybridization or mongrelization occurs, and has frequently occurred, in the human family, this finding also would seem to have a considerable application in man's own world.

At the outset of this presentation we noted that frequently repeated egg-laying in doves was associated with change in sex ratios. Later we saw that this resulted in size, chemical and metabolic changes in the ova. It is therefore evident that if we can analyze the several changes which occur at an, or at each, ovulation period we can approach an understanding of the forces which induce or accompany these changes in metabolism and in sex. During the past six or seven years we have thrown some effort into the study of this matter. The results of these studies have been condensed into the form of curves.

The central vertical lines of Fig. 7 indicate the points in time at which an ovum or yolk leaves the ovary of the dove. Time is read on the base-line from left to right. The size or amount of each thing measured is expressed as height from this base-line. You will notice that

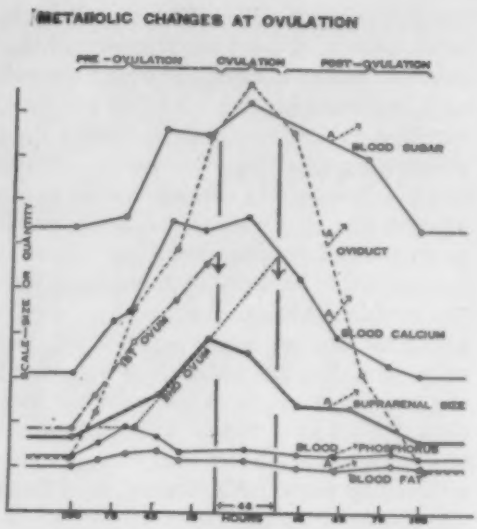


FIG. 7

two ova break away from the ovary—the first, at the left vertical line; the second, occurring 44 hours after the first, at the vertical line on the right. This interval between the two ovulations is spoken of as the "ovulation period." A period of 108 hours preceding the first ovulation we call the pre-ovulation period; a similar period following the ovulation of the second ovum we call the post-ovulation period. These periods have been found to be well-defined and natural things. Our measurements have shown that one of the small eggs of the ovary takes up a new rate of growth, a rate 26 times the former rate, at about 108 hours before it attains its full growth and breaks away from the ovary.

It is also found that the oviduct or uterus, which conducts the egg from the ovary to the exterior, begins to grow at precisely the same time that the first ovum starts its new rate of growth. And indeed we now know that it is one of our regulators of metabolism—namely, a hormone produced within the ovary—that is released into the blood at this time and is thus carried to the walls of the resting, sleeping oviduct, where it makes this organ begin at once a degree of growth

which is almost unheard of elsewhere in adult tissues. Under the stimulus of this internal secretion from the ovary the oviduct increases its size by 1,000 per cent. within a period only a little longer than 108 hours; after another period of 108 hours following the second ovulation the oviduct has again atrophied and shrunk to its normal resting condition. Here it is clear that the growth stimulating hormone which is released from the ovary is produced during a short period of time only, certainly not after the release of the second ovum from the ovary. Incidentally, we have found that the internal secretion of the dove's ovary can be substituted by the same secretion taken from the pig or from the human.

It is well to realize that we here find ourselves in the midst of the many changes brought about by the organs of internal secretion. Ovulation day in the pigeon is indeed mobilization day for the small but powerful army of endocrines.

Your attention is next directed to the curve which describes the size changes observed in the suprarenal glands. At the same time that the first ovum starts its rapid growth, the suprarenals also begin to increase in size—reaching a maximum closely coincident with the time at which the ova leave the ovary. The suprarenal gland—there is one above each kidney—is really composed of two organs of internal secretion, the cortex and the medulla. The cortex produces a hormone which has not yet been isolated, nor even discovered, but it is known to exist and to be essential to life. The medulla secretes a hormone which we commonly know as adrenalin. One of the effects of this hormone is to increase the amount of sugar in the blood. Since our investigation had indicated that both parts of the suprarenal gland had increased in size at this period we wished to know whether they had also increased their function or activity. To determine this, in the case of the medulla, we could find out whether the amount of sugar in the blood increases at this same time. This was studied with the results shown by the curve—the blood sugar is increased by about 20 per cent. This increase, together with the size increase of the medulla itself, supplies evidence that more of the internal secretion which we call adrenalin is being poured into the blood at this period.

The parathyroid glands are also organs of internal secretion, and during the past three or four years it has been learned that the amount of their secretion is very directly related to the amount of calcium in the blood. We have, therefore, measured the blood calcium at various points over this period in order to obtain information as to the part played here by the parathyroids. The result is extraordinarily clear. The normal amount of calcium in the blood is more than doubled at the approach of this particular reproductive period. It returns to normal value at 108 hours after the second ovum is ovulated. This probably means that the hormone of the parathyroids is much increased in anticipation of the release of an ovum from a very distant organ—the ovary.

We have recently measured the amount of fat and phosphorus in the blood at normal periods in the life of the bird, and at the particular period under discussion here. The curves show that both these elements begin to increase in the blood at 108 hours before an ovum is ovulated. Both fat and phosphorus attain maximum values early in the preovulation period, instead of coincidentally with the ovulation period as was found for other constituents of the blood. From this fact we obtain some evidence that a hormone of the ovary is responsible for these two changes in addition to causing the oviduct to enlarge.

We greatly need to know the means by which the ovary is stimulated to begin its work. Within a year Smith, and Zondek, have shown that in mice and rats it is the anterior pituitary body that thus stirs the ovary into maturity and into reproductive action. Our labora-

tory can now report that this result has been extended to the birds. It is thus becoming evident that in all higher animals it is a hormone of the anterior pituitary body that decides the age at which ova and sperm will begin to be formed or matured. We must, therefore, assign the pituitary a share in starting the growth of an ovum, which in turn seems to be the signal of the ovary to the rest of the endocrine company to go into action.

This concludes our examination of the considerable series of changes in the activity of a number of organs of internal secretion, all of which are closely timed to the period of growth and release of an ovum. You will now recall that when the doves were made to ovulate repeatedly the yolk-size was gradually increased, the burning power of the ova was decreased, and an excess of female offspring developed from the ova thus modified. This illustration indicates—at each point provided with an arrow—that under such rapid egg-production the several endocrines responsible for the values plotted here were forced to take up a new—often a maximum—rate of activity instead of lapsing for weeks into a period of comparative rest. We thus discover a part of the basis which repeated ovulations provide for metabolic change and sex change in ova. In obtaining these results our laboratory has had the help of various assistants and collaborators.

I must confess that the data placed on this graph also bring you as nearly as I can hope to take you into the midst of the fine adjustments effected by internal secretions to meet one single phase of reproduction.

We must now, for a few moments, turn to the final division of our subject. We shall see that the recently found prominence of many of the internal secretions in the processes of reproduction makes it possible to consider anew the place which the organs of internal secretion occupy in the scheme of animal evolution.

It is here necessary to direct one preliminary thought to the nervous system. It is a rule that there is no riot within an organism. There are two very complicated and wholly different systems of efficient control. Beyond and around the outlines of the endocrine system which is sketched in Fig. 8 we ask you first to visualize the nervous trunks and networks which may be said to represent the "telegraphic service" of man and bird. Despite the enormous com-

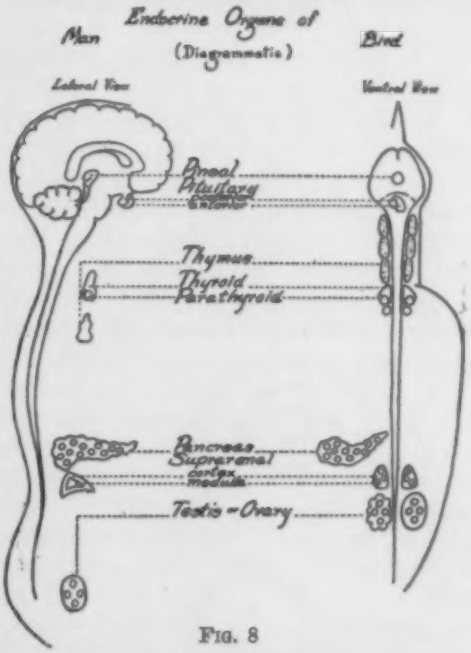


FIG. 8

plexity of this telegraphic system, most of the changes which are connected with reproduction in the bird are found not to be under its control. That control is exercised by the isolated structures whose names and positions are shown in the figure.

The "telegraphic service" is extremely rapid but it has proved entirely inadequate to the needs of so complex an organization as a higher animal. In these animals what we may call a "postal" service has been very exten-

sively developed. This postal, or "chemical messenger" service, is of course the system of internal secretions.

Though a particular organ of internal secretion sometimes looks quite different in the bird and in man, the important chemical substance which it prepares and throws into the blood—that is, its internal secretion—is probably quite the same substance in both man and bird. Except in the case of the pineal—which has not been investigated by us—we have obtained evidence for an equivalent physiological action of all the hormones of the bird and mammal indicated here.

A moment later we shall want to use the fact made clear in Fig. 9. We try to picture quickly the functions of the thymus gland. In our material, which happened to be animals that place albumen, shell-membrane and egg-shell around every egg, it could be shown that the production of these substances is under the control of a thymus hormone which I have called *thymovidin*. In the absence, or practically complete absence, of a thymus it was found that, though the ovary could function normally and could produce ova of normal size, little or no albumen and shell could be secreted. The point needed for our present purpose is that the service performed by this puzzling organ has now been found, and it turns out that its primary function is concerned wholly with the processes of reproduction.

The points at which our various studies have made contact with the internal secretions have, in our opinion, provided a basis for a new conception regarding their place in the general scheme of animal evolution. Table 2 will aid in the presentation of this point. We find that nearly all of the internal secretions are intimately concerned in the processes of reproduction or of sex. And that the only hormones not thus concerned are engaged in the regulation of other *irregular rhythms*. Reproduction is itself a highly rhythmic process.

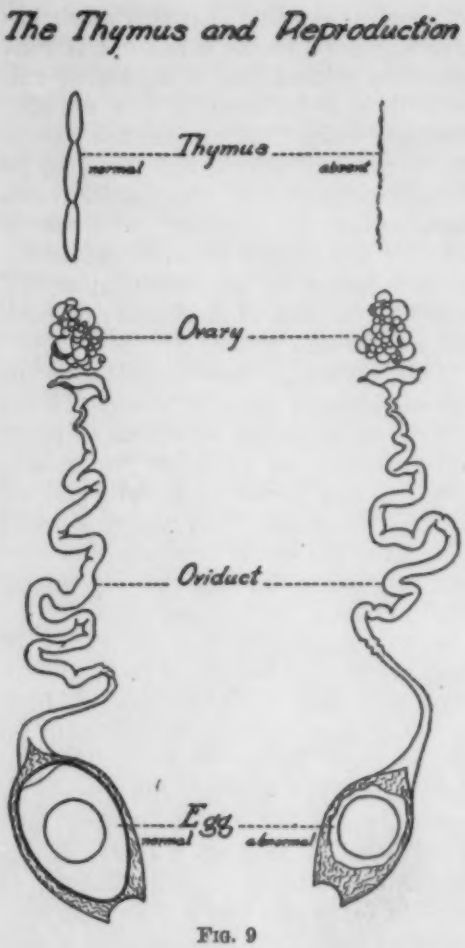


FIG. 9

It thus appears that the "postal," not the "telegraphic," service has been found the efficient method of coordinating irregular rhythms in higher animals.

In the table we give the long list of internal secretions which are now known to be definitely related to reproduction or to sex (those written in parentheses are possibly not true hormones). In another column, at the bottom and to the left, we list those hormones which other investigators have hitherto found no reason for classifying as reproductive hormones. But earlier in this hour two of these three hormones were shown to be concerned in reproduction. You will recall the changes in the blood sugar

TABLE 2

TRUE HORMONES CLASSIFIED WITH REFERENCE TO RHYTHMIC PRODUCTION AND TO THEIR RELATION TO REPRODUCTION AND SEX

METHOD OF SECRETION	UNRELATED TO REPRODUCTION AND SEX	RELATED TO REPRODUCTION OR TO SEX
RHYTHMICALLY SECRETED	(GASTRIN) SECRETIN	(CORPUS LUTEUM) (PLACENTA) (FETAL—FOR MALE SEX)
CONTINUOUSLY, BUT FLUCTUATING	ADRENAL PARATHYROID PANCREATIC	OVARY THYROID POSTERIOR PITUITARY TESTIS THYMUS ANTERIOR PITUITARY INTERRENAL CORTEX (PINEAL)

curve (adrenalin), and in the blood calcium curve (parathyroids), at ovulation. We should note that the amount of sugar in the blood is largely the result of the joint action of adrenalin, and of insulin—the hormone of the pancreas. Our laboratory was able to show that injections of insulin made thrice daily effectively prevents the normal increase of blood sugar at ovulation, and also effectively prevents ovulation taking place at all. The only remaining hormones, gastrin and secretin, are concerned in the rhythms of digestion, and they are themselves rhythmically secreted.

We thus learn that nearly all the internal secretions are intimately related to reproduction. This fact has so many impressive associations that I am tempted to suggest that the evolution of the endocrine organs themselves is largely tied up with the elaborate systems of reproduction present in higher animals. It is here only possible to state briefly some conclusions, almost without reference to the evidence. A very simple form of "chemical regulation," much simpler than that involving true hormones, is present in the plants and lowest animals. This form of regulation is older than the nervous system. But a true hormone—a true internal secretion—has not been found in any animal lower than a cray-fish or a leech. The nervous system—both central and sympathetic divisions of it—is present in much lower animals.

The organs of internal secretion are, therefore, of more recent development in the animal series than is the nervous or telegraphic system. The endocrines appeared late, not early, in animal life. It is now, I think, also evident that all of the internal secretions are specially and peculiarly concerned in the regulation of irregular rhythms—and above all in the essential species-preserving rhythms of reproduction. These facts provide some basis for the view that in higher vertebrates and man these organs of internal secretion probably supply the chief source and hope of further evolutional advance. These are the relatively new structures; probably most of them exist in vertebrates only; they are definitely concerned with regulations and correlations; they largely dominate growth and individual development. Where they are present and endowed with such power, how can they escape a large share in further specific and racial advance?

Let us now consider a final item that has a bearing on the remarks just made. Six or seven years ago we decided to test whether—starting chiefly with birds known to have one or another type of reproductive disorder—it was possible to establish races which would perpetuate their abnormalities; and more particularly to see whether we could establish some races with large thyroid glands and other races with hereditarily small thyroids.

Parts of our success in this effort are shown in Fig. 10. You will see that we have readily established some races of ring doves in which we can confidently predict that the offspring will be provided with large, or with small thyroids. During the four or five generations thus far studied the parents of each generation, and the offspring of each generation, have held with fair consistency to a high or to a low level. Success here means that in this material we now have

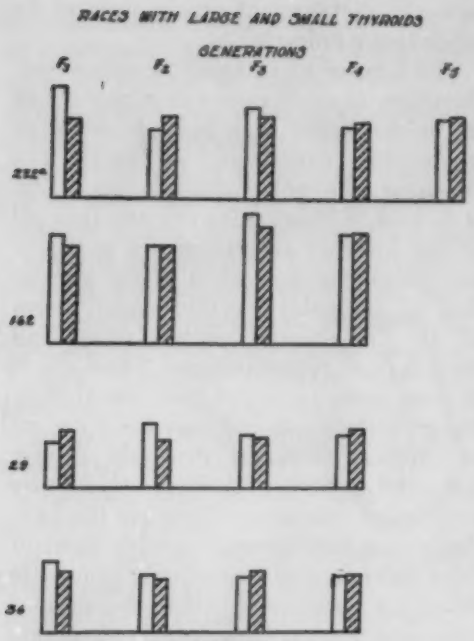


FIG. 10

a chance to learn the perils and advantages to a race of hereditarily large thyroids, or of hereditarily small thyroids—a chance hardly possible in any other known living material. This result also demonstrates that the normal mechanism of heredity can operate in the perpetuation of small changes in the endocrine organs, *i.e.*, in those relatively new organs which in higher animals are taking so large a share in the regulation of growth, of capacity, of health, of reproduction; the same organs whose further modification in these higher animals is, on our view, probably so closely bound up with further evolutional advance in vertebrate animals.

We began our look into the processes of the living world with the observation that two types of reproductive difference, namely, a difference induced by rapidly repeated egg-laying, and a difference effected through fertilization by sperm from a very foreign species, certainly change the sex-ratio and possibly involve a reversal of sexuality. This "possibility" of sex-reversal has been converted into actual demonstration. Sex is reversible, and this is more readily effected in the earlier life-stages. In accomplishing this latter result it has been made altogether probable that maleness and femaleness are really founded upon a difference in metabolic rates. In turn it has been observed that these metabolic differences rest largely upon the internal secretions, and that these secretions are peculiarly and specially related to reproduction. Also, that the internal secretions are relatively recent arrivals in the evolution of animals. Finally, we have seen that new races with size differences in at least one of these endocrine organs—the thyroid—have already been established. May we not say, these races have been created, and that since we are assured of the inheritance of variations of capacity in these regulators and coordinators we here obtain a not-too-distant view of a significant element of our own past and future evolution?

Some of these several problems are by no means fully solved; it is hoped that the work of our laboratory, as this has been discussed here, has contributed a mite toward their solution.

If, in conclusion, this digression of your thought from stars and atoms leaves you with a sense of having entered a nebulous and difficult region, you will be sharing another of my own impressions. The restricted realm of the living, though so near to us—though we are a part of it—is one on which the sunlight, or even moonlight, of definiteness and rigid predictability is scarcely risen. Still, spurred by the notable successes of workers in the more exact sciences, the student of life-processes uses such means as he can to find the rules that apply to the orderly associations of complex molecules which form a living thing. Almost necessarily our efforts lose in precision; but one and another life-process we must measure, since this is the only means we have of arriving at an understanding of ourselves.

HOW IT IS DONE BY THE CHEMIST

By Professor D. B. KEYES

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INDUSTRIAL chemical research has been the subject of much conversation in recent years. Much has been written about its importance and much about its results but little has been said about how it is done. The public still believe it is an art acquired by few. The great research genius of chemical industry is still believed to be a rather impossible creature who spends his hours in profound thought among his test tubes and weird machines. By secluding himself in his laboratory, concentrating entirely upon his problem for a period of many years, he is thus able to have ideas far above the common herd and thereby acquires great fame for himself and vast financial profit for others. Nothing could be further from the truth.

To-day, industrial chemical research has been systematized and standardized. Any desired result can be obtained if sufficient men, money and time are available. The element of luck has been reduced to a minimum. Fortune still dictates the quantity of energy necessary to acquire success but that is all. Fortune is the catalizer of unknown positive or negative value.

On the other hand, romance and interest has not fled from this field of work; quite the contrary. To-day the joy of accomplishment in industrial chemical research can be had by the many and not as formerly, by the few. It is the delightful purpose of this article to prove this statement.

One of the most interesting and most common types of research in our chemical industries is the development of a new and more efficient process to produce an old and well known product. The work on such a problem has been standardized. The order of procedure is as follows:

1. A thorough review of the literature.
2. A selection from this review of the best method so far developed for the particular conditions required by the problem.
3. A listing of all the factors involved in the reaction or method.
4. A listing of all methods of varying each factor.
5. A selection of the factor which shall be varied first and the method of varying it.

A rather remarkable piece of work[1] was done some years ago which will illustrate this standardized method of procedure. Immediately after the Armistice a certain chemical company found itself with large stocks and large capacity to produce ethyl alcohol and dilute (10 per cent.) acetic acid and with no adequate market for either. It was thought that ethyl acetate formed by the reaction of alcohol and acetic acid might be a profitable compound to manufacture. A thorough review of the literature was made. The text-books stated quite conclusively that ethyl acetate can be made only with concentrated acetic acid, absolute alcohol and appreciable amounts of sulfuric acid, the catalyst. Even then the yields were rather low. The process selected was naturally as follows:

$$\text{Acetic acid (10\%)} + \text{ethyl alcohol (95\%)} \xrightarrow{H_2SO_4} \text{ethyl acetate} + \text{water.}$$

[1] Covered by U. S. and Foreign Patents.

From an economic standpoint either this reaction would be made to work or the entire development as far as this plant was concerned would have to be abandoned.

The list of factors were evidently as follows—pressure, temperature, catalyst, acetic acid, ethyl alcohol, ethyl acetate and water.

Pressure and temperature could be varied over wide ranges. The remaining factors could be changed both from a physical and chemical standpoint.

For the preliminary experiments in the laboratory change in concentration of the sulfuric acid was tried. This was done for the simple reason that it was easier than finding a new catalyst of different chemical composition. The results were gratifying. It was found that only a relatively small concentration of sulfuric acid was necessary to bring the reaction to equilibrium.

A new problem immediately presented itself. How could one disturb the equilibrium and obtain 100 per cent. yields. It is well known to those who are familiar with equilibrium reactions that an increase in concentration of the raw materials will disturb the equilibrium in the right direction. It was also well known that a lowering of the concentration of the final products would help produce the desired results. It was, or rather is now, quite obvious, what was the proper selection of factors and variation that should be tried first.

A mixture was made consisting of ethyl alcohol in considerable excess, dilute acetic acid and the proper amount of sulfuric acid. This mixture was passed into the side of a fractionating column. It was found that water and the sulfuric acid came out at the bottom, while a ternary mixture of ethyl acetate, alcohol, and water came out the top. The ternary mixture had a higher vapor pressure than the water and sulfuric acid mixture. As those facts were known the results could have been predicted. It should be noted that no acetic acid appeared; it was entirely consumed in the reaction. On the basis of acetic acid, the yield was 100 per cent. This was brought about by increasing the concentration of ethyl alcohol in the original mix, and permitting the fractionating column to reduce the concentration of the products ethyl acetate and water by removing them from the reaction zone. It was too difficult to increase the concentration of acetic acid, so it was not attempted. The fractionating column also reduced the alcohol concentration which would have been detrimental had not a large excess of alcohol been added in the beginning.

Still another serious problem presented itself. The yield was 100 per cent., but the product was a mixture and not pure ethyl acetate as desired. It is customary to fractionate such a mixture and obtain a pure product. The three however were found to form a constant boiling ternary mixture, so simple fractionation was out of the question. The physical reaction desired might be stated as follows:

(Ethyl acetate, alcohol, water) mixture $\longrightarrow$ ethyl acetate + (alcohol, water) mixture.

It is common to add salt water to such a mixture. In this mixture water alone was all that was necessary. Two liquid layers appeared on the addition of an excess of water. The upper layer contained most of the ethyl acetate and small quantities of alcohol and water. Pure ethyl acetate was obtained by simple fractionation of this layer.

This was, of course not all of the features of this remarkable development. It covers, however, the most important features. It should be noted how closely the development followed the standardized plan of attack. No attempt has been made to under-estimate the intellect, ability and knowledge involved. It

is desired only to show the sound logic and common sense used in the undertaking, and to point out that this very worth while research was successful not because of any wild dreams and very fortunate hunches on the part of the inventor.

There is another type of industrial chemical research which is extremely attractive, but not so common as the one just mentioned. It is the development of a new and more efficient chemical product to take the place of an old product. The new product is often damned by the noun "substitute" or the adjective "artificial." Rayon which is replacing silk is such a product. Phenol-formaldehyde plastics (Bakelite and Redmanol) and the tungsten filament are other examples. This research, difficult as it is, has a suggested plan of attack. One of these proposed plans is as follows:

1. A list of the faults of the old product.
2. A list of similar products not used for the same purpose.
3. A selection from list No. 2 of the most suitable product.
4. Modification of this product to eliminate faults.

It has been known for some time that tincture of iodine is a highly unsatisfactory household antiseptic when applied to open wounds. The content of iodine (7 per cent.) is far too great. In many cases it probably does more harm than good, because of its tendency to attack the living tissue. The solvent, alcohol, (concentrated) is not the sensible thing to put in a cut any more than a red hot iron. Furthermore, tincture of iodine in a bottle with a cork or rubber stopper is not always safe to carry in one's vest pocket or traveling bag. In brief, tincture of iodine as a household antiseptic has its faults.

Among the many compounds of iodine that appear on the market might be mentioned potassium iodate. This product probably has no real antiseptic powers but free iodine does. It has been known for some time that weak acids will liberate free iodine from a mixture of potassium iodide and iodate. It was therefore believed that a dry powdered mixture of potassium iodide, potassium iodate, and an acid salt might be used to replace tincture of iodine. Such a mixture[2] was made. The results were very gratifying. The new product was easily soluble in warm water and quickly released its iodine. The resulting solutions were found to have great bactericidal action on the common bacteria. No irritation caused by a reaction with living tissue was noticeable. The solution could be varied over wide concentration ranges. Even dilute solutions that could be used as a gargle with comfort proved to be efficient as an antiseptic. Furthermore, the dry powder could be carried in perfect safety in pockets or in a bag. The package could be a glass bottle, an aluminum tube, or a pasteboard box.

Here again knowledge, common sense, and a logical plan of attack proved successful and developed a product that should mean much to mankind.

Still another type of research is common in chemical industries. It is the development of a new machine for an old purpose. Many of the fantastic developments since the war have been of this type. The profits of such developments are usually large. This type is little understood and strange to say the method commonly used is the simplest and one of the easiest to follow. It might be outlined as follows:

1. A list of all the basic requirements of the process.
2. A list of apparatus used in other industries for a similar purpose.
3. A selection of the apparatus which will most nearly satisfy the requirements of the process.

[2] Covered by U. S. and foreign patents.

4. Modification of this apparatus to meet the special conditions.

A very interesting case is the recent methyl alcohol development in Europe. Here the method shown above was worked backwards. The famous Haber equipment for fixing atmospheric nitrogen lay idle after the war. The capacity was far beyond the peace time needs. Some brilliant experimenters conceived the idea that it might be used for some other reaction. Carbon monoxide and hydrogen (Water Gas) were cheap and plentiful so they were used as the raw materials in an experimental run. Methyl alcohol appeared as one of the products, probably, much to the surprise of every one. No particular attention was paid to the catalyst in this first run. The Haber equipment was capable of developing high pressures and high temperatures at the same time. This was its unique feature. It was well known that carbon monoxide can not be reduced with hydrogen at ordinary pressures and temperatures. Therefore, it was rightly concluded that with ordinary catalysts, high pressure and high temperatures were basic requirements of the process.

The romantic tale does not end here however. An American concern has started the production of methyl alcohol from methane (Natural Gas) by partial oxidation with air. This was done by utilizing a standard equipment formerly used for another purpose. The design and operation was modified to meet the new conditions. Methyl alcohol can be made cheaper, in all probability, by this process. This means that once again the high pressure, high temperature equipment will become idle and the research workers will be faced with the problem of finding new raw materials. Fortunately there are several chemical elements and compounds left to try out.

About twenty years passed by before we realized that the X-ray machine could be used for anything other than locating the tack little Cuthbert had swallowed.[3] To-day whenever we want to know something about the internal structure of anything, we use the X-ray. Why, because we need a ray that will go through and not be reflected from the surface. It makes no difference whether the material is butter or steel. The basic requirements of our process are satisfied by the X-ray machine.

Oftentimes this type of research is relatively simple. Our great motor fuel industry for many years confined its development solely to increased production. Money spent on producing increased yields and higher grade products did not produce dividends equal to those produced by the same investment in additional production. To-day the tables are turned. Fractionating columns used by the alcohol industry for the last thirty years are now employed in the petroleum refineries. Certain modifications were necessary. Whenever the basic requirements of the process and the function of the fractionating columns were thoroughly understood and appreciated, success was immediate and certain.

An interesting development of this kind has occurred in the natural gasoline industry. In this industry gasoline is obtained from natural gas by compression, absorption, or adsorption. The crude product contains not only the desirable higher boiling hydrocarbons (butane and up) but also the low boiling, volatile, and undesirable hydrocarbons (propane, ethane, and methane). This volatile constituent is removed by "weathering." This is a simple distillation in a still that no self-respecting bootlegger would think of using. The result of using such an apparatus is quite evi-

[3] This hysteresis of the human mind has been pointed out by S. C. Gilfillan in an excellent article entitled "Who Invented It," published in the Dec., 1927, issue of THE SCIENTIFIC MONTHLY.

dent to any one familiar with the basic principles of fractionation. The volatile material is removed and with it appreciable amounts of the less volatile and desirable material. The simple substitution of a fractionating column for the eighteenth century still has given in one case a 45 per cent. increase in yield.

Sometimes the proper selection of apparatus is difficult and sometimes it is a matter of chance. An excellent illustration of the latter is given in the story of the famous New Englander who sent a cargo of warming pans to the Tropics, and the ingenious native found them useful for concentrating sugar syrups.

Often the necessary modifications of the machine are not apparent. There is a story told of Mr. Edison in the early days that will illustrate this point. Mr. Edison was adapting the horse shoe magnet to the electric motor. The magnet was placed vertically with the armature at the bottom between the poles. A heavy iron base was necessary, but this produced an iron connection between the poles. The lines of force were promptly shunted away from the armature and the machine would not work. Mr. Edison and his colleagues worked long hours to devise a non-conducting material to be placed between the poles and the iron base. A fairly satisfactory material was devised and several of these machines were sold. A few years ago some university laboratories still had this model on display. A master mind, the story does not include his name, finally pointed out to Mr. Edison that the problem could be solved by merely turning the machine upside down. No metal connection between the poles was required as the iron base was on the other end where it did no harm.

Many more illustrations of this fascinating type of research could be given. The most interesting and perhaps most far reaching in their significance are developments of this type that are underway at the present moment. They are, however, in that delicate state that premature exposure might prove fatal. It is hoped that the reader will be content with the evidence already submitted.

SCIENCE AND CONDUCT

By Professor A. W. MEYER

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FORTY years ago so sound a writer as Matthew Arnold joined in the lament over the eclipse of the humanities by science. Although he uttered some words of reassurance these must have been forgotten, for even to-day there are those who tremble lest "wisdom and joy die in a test-tube."

Since Arnold, of Rugby, declared that "Rather than have physical science the principal thing in my son's mind, I would gladly have him think that the sun went round the earth, and that the stars were so many spangles set in the bright, blue firmament," Matthew's attitude need not surprise us, and he who has not cast suspicious glances at science in our own day has an even-tempered soul indeed. There are even those who profess to believe that science is a curse rather than a blessing, and I may recall the remark of a scholarly friend who declared that he was not aware that he owed anything to science except the electric light. Taken as a confession this might pass in silence as it did, but taken as a valuation of the service of science to him it was benighted indeed.

I am certain that such verdicts as these on science do not rest on any lack of heart, but on a lack of knowledge of modern life and on a misconception of what science really is. In the minds of these good people, science is supposed to be a collection of so-called dead facts, and minister only to man's lower wants. To them the scientist merely is a "fact peddler." Even a very liberal contemporary clergyman thinks that "all organisms are to him (the scientist) nothing but objects for observation and report," and some scientists regard science merely as classified knowledge. If it be the latter, then it is mummified and ready to be labeled and exhibited in museums, side by side with other mummies and fossils. Since Berkeley regarded the abundance of fossils as the possible cause of scurvy and hypochondria among the British people, I am tempted to add that such a view as this of science should give others than the British, hypochondria.

A mere collection of facts no more constitutes science than a collection of pigments constitutes painting. Facts are only the materials upon which and with which the mind of the scientist, as that of the humanist, works. The temple of science is, to be sure, constructed with facts as foundation units, but no building can stand without mortar and none ever was shapen without the directing mind of an architect. Separate pigments alone can not make a Sistine Madonna and in the rearing of the temple of science the play of the imagination also had a large part. It too is the product of creative thought and here is one place where science and art meet.

We judge the rôle of art by the influence of the final product, and not from the effect of the separate materials, and that also must be our attitude toward science. The scientist too is a poet —a creator—and breathes life into the facts which he discovers. He does not kill live facts, but discovers so-called dead facts and makes them live. He also has his ideal world and if poetry has a soul, then science too has one and who would deny that science has in the past set the soul of men aflame and that it shall do so in the future. The starry

sky has not lost, but gained in grandeur through the hand of science. Although "astronomy has decentralized the world" it also has "revealed to us, as by an angel's hand, the scope of the heavens and the import of the stars." . . . "The more a man knows, therefore, the more full of wonder he finds the world." Were this not so, then the ox in the stall would stand in awe and wonder at the universe as much as man.

Science does not, in the words of Chateaubriand, "ask man to live with a full heart in an empty world." It does not destroy mysteries but fills the world with meaning. It is not a hod carrier, but a torch bearer. "Scientific knowledge teaches us to hear the innermost soul of things vibrating in unison with our own souls, and it is just this which enables us to understand them and to absorb into our Ego the revelation of their true being." According to Wilbois "Scientific life is then the first step towards loftier spontaneity; invention is fulfilled in virtue." Science can not know beyond this life, but there is nothing to prevent it from looking beyond. For it too "Omnia exeunt in mysterium."

In the solution of every scientific problem many others are raised. Every new fact that is revealed suggests new relations and the existence of other facts not dreamt of before. Hitherto unknown facts and relationships are constantly being revealed and so the mystery always broadens and deepens. A geocentric universe held the cramped thoughts of men until a heliocentric universe displaced it, and this in its turn has given place to a truly staggering conception until infinity and eternity both stare us in the face.

Science is daily making discoveries both in the direction of the infinitely small and the infinitely great until, as Abbott wrote, "Not the awful immensity, but the infinite complexity of the universe compels thoughtful men to feel that there must be a creative intelligence behind it all." Although I do not feel that complexity more than anything else should compel men to believe in the existence of a Supreme Being, I never have felt that science compelled any one to abandon such a belief. As Aliotta says, "The rationality which science postulates in nature leads us to Divine Consciousness, as a necessary complement, because a reason, an objective system of concepts and ideal relations, without consciousness, is something we can not understand."

It is heartening that theologians have caught the larger meaning of science. The dean of St. Paul's, for example, wrote recently: "Science is not, as some have erroneously supposed, a description of fact without valuation. Such a description would be utterly impossible, and it should be superfluous to point out how widely the world, as known to science, differs from the final analysis of material objects into electrons or protons." The scientist must evaluate facts in determining their relationship and in trying to determine their significance in the world scheme. Whether beings are normal or abnormal is a vital matter to him, and organisms are more to him than objects for observation and report, if by that is meant that he merely is an amanuensis for nature, an automaton.

I am not, to be sure, using the word science in the narrow, antediluvian, but in the broad, modern sense. The rough grouping of physical, biological and social sciences serves my purpose very well, provided it is not forgotten that the history, the development, and the philosophy of each are integral parts of them. So considered science has an inner, as well as an outer, content, and that, to be sure, it had from its beginning. Science in this sense assuredly does more than "turn our spindles, haul our goods, and coin our money," and perchance relieve us of daily physical distress in the later days of life.

The most obvious surely are not the most ennobling effects of science. It has made contributions, not only to our material needs, but to our higher culture and, I confess, I have often envied critics of science the sweep and finality, as well as the assurance, with which their verdicts concerning it have been delivered. They prompt one to counsel, "Let us fold our tents and steal away, for there is nothing more to do. All is settled now." I believe that the explanation for this confident derogatory attitude lies in the fact that some of these good people have not even realized the modest hope of Matthew Arnold, who avowed that he might care to know as much science as "he could conveniently carry." However ample in other respects, Arnold's conveniences apparently were rather limited in this regard.

In spite of the oft-cited confession of Darwin, devotion to science does not in itself imply indifference to literature, music and other fine arts or blind one to the fruits of friendly intercourse or to the great rôle of religion as a social force and a personal guide and comfort. The scientist, as the artist, may be preoccupied with the field of his choice to the neglect of other interests, but he does this not because he is a scientist but because he is human. He probably is no greater an offender in this respect than the humanist, and it should not be forgotten that science as well as literature, the fine arts and music also is a product of the human spirit.

In the face of de Garmo's warning, in the days of my young manhood, that "we have labór for our pains if we look for the embodiment of ethical truths in nature and natural science," I made bold to look for them long ago. Such pronouncements as de Garmo's regard the study of science merely as a study of dead things, and exclude the social sciences. They overlook the fact that nature includes what is living as well as what is dead and that man, himself, always has belonged to the study of science. "The end of science is not to attain to abstract laws, but rather to comprehend the facts of experience in the light of laws." . . . "The essential thing is not to reproach scientific knowledge with the abstraction which is a practical drawback that can not be eliminated in the realm of philosophy" even.

The mechanistic or any other one-sided conception of nature is only a partial view, and no matter how great the change wrought by the scientific method no one can claim that a completer view of nature would be hampering to future progress. Mathematical formulae and physico-chemical laws are inadequate in biology. To try to reduce everything to a mathematical basis well may reveal many undreamt of relationships to us, but it does not seem that it ever can give any one a full interpretation of living things for it begins with the assumption that life can be expressed in a formula. As Maxwell wrote: "There are many things in heaven and earth which, by the selection required for the application of scientific methods, have been excluded from our philosophy." Nature assuredly is not merely what a mathematical formula can state, but also what I can experience and can not say in words. The world of the mechanist, like that of the traditional religionist, is a make-believe world. Neither is real.

Any one familiar with the history of science realizes that there has been a steady though gradual expansion of its domain. In the absence of scientific knowledge man had to depend wholly upon divinities for protection against famine, pestilence, overpopulation and war. He has learned better regarding the first two, and must do better about the last. Against famine, pestilence and overpopulation only science can win the battle, and when the evils and woes of strife will become sufficiently known, the hearts of men will be turned toward peace. The bare facts will displace the

gods also here just as soon as men fully realize the futility and comprehend the tragedy of strife.

I know full well that Pallas Athene was endowed with a sword as well as an owl, but that does not excuse educated men from declaring that "the bulk of science and research only require accuracy of observation, careful experiment and logical deduction, and a rascal can perform those requirements as well as an honest man." In comment I should question the word only, and then add that a rascal also can read the Bible, can pray and preach, and indeed not infrequently does so, to very respectable people. Yes, a rascal can do that, but a fool can not. A high morality does not exist among degenerates. A developed intellect is essential to good conduct. Not only that, but knowledge is necessary for right action in many things, for no matter how well developed an intellect may be, without the requisite knowledge no one can realize the probable consequences of his acts. Good intentions alone will not necessarily prevent any one from committing anti-social or unmoral acts.

It is said that only saints can lead a truly religious life, and I am certain that only sages can lead a truly scientific life. The bearings of modern science upon life are so manifold that the most conscientious will find themselves again and again unwittingly acting to the detriment of their fellows. Every one of us has had abundant occasion to say "I meant to do the right thing, but I did not know." This, it seems to me, is a juster interpretation of many errors in conduct on the part of decent people than to hold that they knew what was right but did not do it.

I know that it is customary to speak of this as a scientific age, and to regard ours as a scientific civilization, but that is a slander upon, as well as a tribute to science, for our age is scientific no more than it is Christian. We are not educated scientifically even. A study of the courses taken by students at one of our foremost universities, for example, showed that only about one tenth of their time was spent on natural science in their entire progress from the kindergarten to the end of college life. Were modern life not characterized by the lack rather than by the predominance of use of the scientific method, quackery could not find a multitude of patrons among all classes. We do not use but misuse science. In the words of Soddy, "We have fooled with the achievements of science." Were science really heeded, some of the most perplexing and distressing social problems would have found a better solution long ago.

It has often seemed to me that it will be far more difficult to establish a scientific civilization than a religious one. Belief spreads easily, even when it concerns scientific things. It does not take long to believe that I-On-A-Co cures all ills, but it would take long indeed to prove it! Knowledge comes far slower than belief, for it is the result of individual effort, of toil. It may have been this which caused Stevenson to say that the lamp of science smells terribly of oil, but it frequently is forgotten that he also added that its light shines very brightly.

Science is slow and halting and can not hurry. It must be circumspect. Dogma, being ready-made, is always at hand. It knows none of the impediments of science. Science encourages the suspension of judgment, not the abdication of it. It inculcates a judicial attitude, and by revealing man's place in the world, teaches him humility and that should make for tolerance. It does not, it is true, invariably effect these things, but surely that is not surprising, for the far older humanities, and the still older religions, also have failed to do so. They too could not wholly overcome human frailty.

I know that the open-mindedness,

freedom from personal bias, reverence and humility, etc., which science tends to cultivate, can only help to tell us what to do. They do not tell us to do it. They do not embody the categorical imperative. But let it not be forgotten that science declares that no one can escape the inevitable and that every one violates the laws of nature at his peril. This is what the decalogue tells but I may violate the latter and supposedly be damned for it in a conjectural future life, while if I violate a law of nature I will be damned for it here and now.

Science supplies motives for right action and assures a better judgment. The conception of harmony and fitness in nature also tends to develop the moral sense—at least indirectly—and a study of living things, in many scales of life, does this directly. For science reveals the effects of acts upon the individual, as well as upon the community of beings. It shows how individual and community welfare are interrelated and achieved in nature and that includes man. It shows that happiness depends upon conduct in conformity with law—conduct that takes cognizance of group, as well as of individual, interests. That the only great concerns are community concerns, "the only great sorrows, public sorrows," and that should make for unselfishness. It encourages integrity and a love of and a loyalty to truth, wholly regardless of the consequences. Even a critical writer such as Webb admits that "it is beyond question that scientific research is a school of many virtues, including some which religion in general and Christianity in particular, have not promoted," and Fosdick even declared that "There is such a thing as the religion of science, where men at all costs and hazards live for the love of truth."

Two tenets of physical science, the indestructibility of matter and energy, imply and constantly remind one of the eternal. Instead of a world which was created a few thousand years before Christ, and whose ending often was confidently anticipated in the past, science has given us a universe whose extent exceeds human comprehension, and whose age must be reckoned in countless eons. This in itself should arouse feelings of awe and wonder impossible without such conceptions, else an ox might experience them just as well as man.

Science, too, has its heroes and its heroism, and the spirit of science is well exemplified in its great men. I can not imagine a better school for morals than the story of the development of science and its rôle in past civilization. Ethical implications lie on all sides. As Aliotta well said, "Science is not the night in which all cows are black." The teachings of science are not merely negative. They show that folly leads to ruin, that disuse leads to atrophy, and these are ethical principles of both philosophy and religion. The parable of the talents is embodied also in science and the teachings of science and the ethics of Christianity coincide in many respects. This was pointed out by Huxley when he wrote, "Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before the fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abyss Nature leads, or you shall learn nothing. I have only begun to learn content and peace of mind since I have resolved at all risks to do this."

We call acts immoral because of the misery they cause, and moral if they promote the common good. Science alone can reveal the misery or the good to us or to others. Experience, to be sure, can do so, but its sphere necessarily is restricted to the individual, and we must learn to depend more upon the experience of others or history will teach us nothing. Our ideas of morals, as our gods, are self-created and changing.

Both are the product of human evolution and he was a wise man indeed who said that one knows a people by its gods. We evolved our morals and fashioned our anthropomorphic gods to suit ourselves. Neither was imposed upon us from without, although in so far as our morals are based upon the feeling of affection, of concern for others, they are instinctive in a sense, and in so far as the feeling of affection is not instinctive, it can arise only upon the basis of knowledge.

The fact that science has revealed the existence of strife among living things has often been held against it, but it also has revealed the presence of altruism and the prevalence of harmony and unity in the universe. However, as long as strife exists it is well that humanity should know about it. Every one knows that a fool's paradise can not endure, and only a fleeting happiness can be secured by thinking one's self in heaven when one actually is elsewhere. Moreover, it may be recalled that Spencer argued that altruism could never have arisen but for the existence of strife. That in order that half of mankind might be altruistic, the other half must be non-altruistic.

Science deals with forces within, as well as with those without, the individual. It demonstrates that there is no escape from the eternal forces of nature, and that collision with them means suffering and disaster, that happiness, on the other hand, lies in obedience to law. By demonstrating the existence of natural law in the physical world, it has led to the conception of natural law in the spiritual world, and by revealing a universal law and order among things, it has revealed harmony in the world and set its face like flint against lawlessness of all kinds.

The idea of kinship in nature was established firmly by science, and this idea can not help but enforce the Christian teaching of human brotherhood. Instead of teaching that man arose in perfection and lost it, and that he can look forward to none but evil days, science encourages men to take heart and to try to achieve a better day on earth. By giving him a better comprehension of his surroundings it has made man feel more at home in an inhospitable universe. As Wyatt put it, "It is science, and science alone, which enables the human mind to pierce the veil covering the inner spirit of nature, and to see the glory behind the apparent shame." It reminds him that he is not necessarily born good and free and happy, but that some of us are born short and others with evil impulses. It alone can reveal the relation between personality and life work, between the physiologic inheritance of men and their personal conduct and social influence.

It has shown plainly that man's lowly origin need not keep him from aspiring to perfection and it does not negate the noble command of the great Florentine:

> Know ye the heavenly seed from which ye came,
> Not for the lusts of beasts were ye compacted
> But that your minds and hearts be set to flame.

However far it may be from its final goal, science bids fair to consider all things in the heavens and on earth, not excluding even the thoughts, the dreams and the hopes of men. As Aliotta has well said, "the scientist does not confine himself to the world of nature, but insists rightly upon submitting even religion and religious feeling to scrutiny." It is useless to put up "No admission" signs. The activity of scientists is self-directed and also engaged in finding schemes which may serve as a guide in the complexity of the phenomena of experience. . . . Scientific truths are admitted by us that we may recognize that they are means for attainment of our ethical ends. Thus religion and science are reconciled in the common origin, which is always an act of pure will." If this be true then science too makes for a broad and liberal outlook

of life and develops a sense of value which James, I believe, regarded as the aim of culture. It can not help but cultivate the critical sense which Arnold regarded as the main value of the study of literature and it constantly is revealing the true and the beautiful, and stimulates the esthetic. I do not, to be sure, hold that all branches of science do these things to the same extent, or that they have this effect upon all who enjoy its fruits. It is a universal solvent of our perplexities no more than art or religion, but it surely gives us a fuller grasp of ourselves and of the world in which we live.

This higher rôle of science is what Berthelot called ideal science. It rises above mere observation and empiricism, and no matter what individual scientists may have thought, science always has had a higher content of value as well as a lower content of fact. It not only reveals the outer world to man, but reveals man to himself. Yet, in spite of all this, Russell confesses that he is still doubtful whether science will prove to be a blessing or a curse to humanity, and a faddist and scoffer, like Coleridge, wrote, in all seriousness, "The motor car and the bicycle then are the two undoubtedly beneficient inventions that science has conferred upon a world which it has otherwise physically defaced and ruined, and morally degraded and defiled past hope, past cure."

Although Russell seems so doubtful about the rôle and the future of science, he sees an only possibility for betterment in a world government established by force in order "to preserve a scientific civilization," which if "once realized will gradually give rise to the other conditions of a tolerable existence." Here, then, is a philosopher who maintains that science has had little influence on our institutions and who as yet is doubtful whether it is a blessing or a curse, but who nevertheless proposes the use of force to establish this so-called doubtful scientific civilization! Even if this civilization merely is tolerable, it must be confessed that other forces have failed to accomplish a better result; and if we are but "bundles of passions and instincts," as Russell maintains, it is clear that nothing approximating a scientific civilization ever can be established, for science rests on reason, not on blind passion and heartless instinct.

As long as we regarded all diseases as visited upon us by the gods, we did not need to trouble ourselves about sanitation and its many serious problems and effects. As long as we regarded the insane as possessed of the devil, we could with clear consciences deride and stone them on the streets and have them perform for our amusement at wedding feasts. It required much earnest search before we learned that a dermoid of the ovary did not convict the unfortunate possessor—sometimes a mere child—of illegitimate sexual relations. Think of the brutal treatment and bitter persecution of luckless little girls in the name of religion and morals for an accident of development in prenatal life! The important thing is not that progress toward better things has been slow in these matters, but that it came solely by the aid of science, and what we formerly regarded or now hold to be right or wrong depends wholly upon the facts at our command.

Science does not deaden but quicken our moral judgments. This has been true, not only in the above, but also in a multitude of other things. It is exactly in the many complicated relations of everyday life that the facts revealed by science help to determine our conduct. Whether it be a personal question such as divorce because of incompatibility; of venereal diseases in the adult or the newborn; the presence of typhoid germs in milk; the disastrous breaking of a dam; the explosion of an oil truck; the occurrence of pellagra, scurvy or beriberi in our asylums; the punishment

of crime; the question of drug addiction; the marriage of near relatives or defectives; or political questions such as matters of government and international relations; in all these things the question of justice and right must be determined upon the basis of the facts. Our conduct must be determined by knowledge and reason, not only by feeling. Inspiration fails us and religion and ethics are helpless without a knowledge of the facts. Can any one, for example, imagine the difference to the world if peace treaties had been made on such a basis instead of that of feeling!

No one could lead an even approximately correct life to-day without the help of science. It gives us wider knowledge of our work-a-day world; and as morality is based largely upon reason and knowledge, it follows that science must remain one of the greatest of influences toward right action. Since it gives us a knowledge of ourselves and also of others, it must tend to increase, not to decrease affection, and in this way further influence morality. As long as I do not know that a certain act is hurtful to myself or to others, I will not be saved, except by painful experience or happy accident, of committing unmoral acts. But I can only learn of what is hurtful from knowledge and experience.

It is strange that Webb held that science "subtracts from the ethical standards it surveys," while stating that "the damaging criticism of men of science during the last two hundred years against the old rational theology, with its proofs of the existence of God, have antiquated a type of view which appeared reasonable to some of the greatest minds of an earlier age. . . . The scheme, which satisfied the imagination of Augustine and of Dante, of Milton and Pascal, it is not indeed possible for us to accept as more than a symbolic picture. It is too late in the day to rehabilitate the credit of the 'Book of Genesis' as a faithful record of the origin of the world and of mankind, or that of the New Testament eschatology as an accurate forecast of their future destiny." Dean Inge—and other theologians—also declared that "the discovery that the earth, instead of being the center of the universe, like a dish with a cover over it, is a planet revolving around the sun, which, itself, is only one of millions of stars, has torn into shreds the Christian map of the universe," and that "science has made the belief in a geographical heaven and hell impossible, or at least very difficult." Hence science apparently is doing exactly what James hoped for when he said that what most men need "is that their faiths should be broken up and ventilated, that the northwest wind of science should get into them and blow their sickness and barbarism away." Indeed, who can fail to admire the courage and integrity of Mill in declaring: "I will call no being good who is not what I mean by good, when I apply the word to my fellow creatures, and if there is a God who can send me to his hell for not calling him so, to hell I go."

Science is helping to make new creeds long before the time referred to by Morley when he wrote, "Science, when she has accomplished all her triumphs in her order, will still have to go back, when the time comes, to assist in building up a new creed by which man can live." Indeed, this new creed is being built daily, although few scientists would go as far as Eliot when he declared that "There would be no perceptible influence on the morals of the race if Hell were quenched and Heaven burned."

Unless there is no relation between religious beliefs and conduct, science must have a very direct bearing upon conduct also if only through its effect upon religious beliefs. It is true that science knows no closed book, that its content and meaning are constantly changing, but so is our conduct. The

moral of to-day was the immoral of yesterday. Science deduces nothing from absolute principles, and as Berthelot said, "What is deduced from absolute principles is an illusion. Whatever pretends to be supported on the absolute, is supported on nothing"—unless, perchance, man could fathom the absolute.

Since science speaks a universal language, and since the fruits of science can be universally used, it should carry its lessons and influence everywhere and also serve as a common bond among mankind. Goethe wittily suggested that what unites us is the common and not the distinguished. Only a world religion could be a universal bond, and for that our greatest religious leaders see no hope. Men are, of necessity, much more likely to think alike in science. Religions have often been the cause of disunion in the past, and unfortunately even to-day still separate rather than unite, nations or groups of peoples within the same nation. There are many kinds of religion, but only one universal science.

Like Prometheus bound, science has cried out long and loud in protest against many social ills and a mass of avoidable evil and woe that beset us. Many of us have had deaf ears because of a lack of comprehension of ourselves, of our fellows and of the conditions under which we live. In the last analysis I can not doubt that a wiser humanity will mean a kindlier humanity. Ignorance and brutishness go hand in hand. We shall no longer put little children to "hurtful labor" when we have a fuller knowledge of what that means to them, to us and to posterity, and when we shall recognize frankly that children are the result of our own acts rather than accidents or a gift of the gods, we shall feel responsible for the use we make of our procreative powers in wedlock as well as out of it.

In the words of Carrere, "For thousands and thousands of years poor humanity has dragged itself over the earth in pursuit of a happiness that ever recedes before it like a mirage; for long ages men, races and empires have clashed, urged on by a destiny of which none of us yet knows the secret; from the dawn of time we have held up to heaven hands that implore unceasingly and begin ever anew; during the whole of time we have struggled and stumbled through the bloody darkness," but who would deny that but for science this darkness would be "bloodier" still? I am not as confident about the future influence of science as Renan, but when a happier day shall dawn, I doubt not that science will have had very much to do with lighting the way, even if it has not been an open sesame to it. Science alone probably can not save us, but it is very unlikely that theology alone can do so, even after being freed from dross. It is more than likely that man shall need all the resources at his command in order to round out his little day on earth in freedom, peace and happiness. Science may free us from all the dead weight of traditional theology, but if we will "strip ourselves of all that we owe to science" then we may undoubtedly, as Voltaire said to Rousseau, "again live on all fours." Indeed, many of our fellow-men, both primitive and civilized, seem to prefer this unscientific attitude in our own time, but as for me, I prefer to say with Carrere, "I have been in their huts, have smelt their dung heaps. No thank you."

THE ELEMENTS AND SAFEGUARDS OF SCIENTIFIC THINKING

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THE teacher of science has an unexcelled opportunity to develop in pupils skill in that type of thinking called scientific. As Dewey points out, science is quite as much a method as it is subject matter. The teacher who fails to drill pupils in the scientific method is not doing his whole duty as a teacher of science.

We are forced to think only when facing a problematic or, as Dewey aptly calls it, "a forked road," situation. It behooves the science teacher then to throw much of his pupils' work into problem form: just how much will depend on the relative importance he assigns to skill in scientific thinking, to scientific knowledge and to appreciation.

ELEMENTS OF SCIENTIFIC THINKING AND THEIR SAFEGUARDS

The teacher who endeavors to direct pupils in acquiring skill in scientific thinking must have a clear-cut notion of the elements that constitute such thinking; he must be on the alert to detect and correct the errors that pupils are most likely to make in the process. The elements of scientific thinking are essentially the same as for any reflective thinking. It is by the increasing awareness of the safeguards that must be thrown around the successive steps in the thought process that science has made its thinking constantly more cautious.

The following outline will present these elements and safeguards:

Elements of scientific thinking	*Safeguards*
Purposeful observation	a. must be accurate; b. must be extensive; c. must be done under a variety of conditions.
Analysis—Synthesis	d. The essential elements in a problematic situation must be picked out. e. Dissimilarities as well as similarities must be regarded. Danger of analogy. f. Exceptions are to be given special attention. Selective interpretation.
Selective recall	g. A wide range of experience is necessary.
Hypotheses	h. All possible ones must be considered. (Fertility of suggestion.)
Verification by inference and experiment	i. Inferences must be tested experimentally. j. Only one variable is permitted.
Reasoning by: 1. method of agreement 2. method of difference 3. method of residues 4. method of concomitant variation 5. joint method of agreement and difference	k. Data must be cogently arranged. l. Judgment must be passed on the adequacy of the data. m. Judgment must be passed on the pertinency of data.

Elements of scientific thinking	*Safeguards*
Judgment	n. must be unprejudiced; o. must be impersonal; p. must be suspended if data are inadequate.

Recognition and Definition of a Problem

It is evident that two things must precede the solution of any problem, namely, the recognition of the problem and its definition. It is only when the student is facing a clearly-defined problem that his observation will be purposeful.

The initial task of a physician is frequently simply the job of defining a problem. A man comes to his office to consult him who only knows he is losing his customary vigor. He has no particular pain, sleeps and eats fairly well, but just does not feel like his old self. He tires rather easily. He has had several colds during the past winter when formerly he rarely caught one. He does not know what ails him, or that anything really ails him; yet he does not feel fully energetic. So the physician proceeds to give him a thorough examination. He takes his pulse and temperature and finds both apparently normal. He uses his stethoscope to listen to respiration and heart beat. There are no signs of trouble. He takes his blood-pressure, makes a blood count, analyzes the excretions. He finds nothing suspicious. He X-rays his teeth and so discovers bad pus sacs on the roots of some dead molars. The indefinite problem of the patient's malaise now becomes a perfectly definite one of how to best rid him of some badly-infected teeth. The patient knew he was facing a problematic situation. The doctor has clearly defined the problem.

A man who is conducting a previously successful manufacturing business begins to be aware that something is wrong. His monthly trial balances show decreasing profits. He runs on for some time hoping things will take a turn for the better, but no improvement comes. Unable to locate his trouble, he perhaps calls in an efficiency expert. All he can tell the expert is that something is wrong—just what it is he can not say. So the expert looks into the sources of raw materials, their initial cost and the cost of delivery at the plant. He goes over the factory and examines all the items that enter into the cost of production. He looks into the location of the markets where the product is sold, the cost of shipment, the expense of the sales force. Possibly he finds production costs are excessively high and on analyzing the various items discovers that the daily output of certain essential machines per man employed on them is low as compared with other similar factories with which he is familiar. The machines are old and inefficient. The indefinite problem, merely that something ails the business, now becomes the very definite one of the replacement of these antiquated machines with modern models.

Aloisio Galvani (1737–1798), a physician and professor at Bologna, was preparing frogs' legs for his wife. She was ill with some stomach trouble and this delicacy had been prescribed for her. He had skinned a number of the frogs' legs and had laid them on the table when he was called out of the room. A student of his was experimenting with a frictional electric machine on the same table. His wife happened to touch a scalpel to the nerve of a frog's leg when a spark jumped from the electric machine to the scalpel and the leg twitched violently. She related this to Galvani. He recognized in this a problem, not merely a curious fact. He tried to get additional facts. He hung frogs' legs on iron wires on an iron trellis in his garden while a thunder storm was in progress. The legs

twitched violently. He laid frogs' legs on metal plates indoors and touched the nerve with one end of a wire, the other end of which was in contact with the metal plate. Again he observed the twitching of the legs. When, however, he laid the legs on a glass plate and used a glass rod to connect the plate and the nerve, there was no twitching. In these experiments he was trying to define his problem which finally shaped itself into the question whence came the electricity in these frogs' legs? He later decided, erroneously, that it was generated in the nerves. In spite of a wrong solution he had seen and defined a problem.

One wonders in looking back over the history of discovery that men were so slow in making discoveries that now seem readily apparent. Of course "hindsight" is notoriously easier than "foresight." Yet much of the difficulty has come from failure to see that there was a problem and failure to define it clearly. When even physicians believed that disease was a dispensation of Providence, there was possible no problem concerning a cure. Suffering and death were the inevitable lot of man and unquestioningly accepted as such. When "sore throat" included such diverse things as scarlet fever, diphtheria and measles, the problem of a cure could not be undertaken, for the problem was not clearly defined. Typhoid and typhus fevers were confused for a long time and could not be successfully treated or a cure discovered because the problems involved were not clearly defined. The recognition that a problem exists and a clear definition of it are absolutely essential steps. It is immensely important to develop in pupils the problem-seeking, problem-defining attitude of mind.

Historic Instances of Scientific Thinking

The history of science is replete with many instances of the interplay of these elements in the solution of problems. Convex lenses were known from very early times. The Greeks certainly used them as burning glasses. When lenses were used as spectacles and in the microscope and telescope in the early seventeenth century, the problem of exactly how they affect the light passing through them was forced upon the attention of the early scientists. Many experiments were performed, using lenses of varying curvature, both convex and concave, passing a beam of light into glass so it struck the surface at various angles and noting the amount of bending or refraction. So a body of fact was accumulated by purposeful observation. Such experiences were analyzed to pick out relevant essentials. Reasoning on the basis of these led to the tentative hypothesis that there is a relation between the angle of incidence and that of refraction, such that the greater the former, the greater the amount of refraction. This *principle* was confirmed by additional experiments; so the judgment stood as a bit of new knowledge.

But could this relationship be expressed more exactly? Kepler continued the experiments and from a study of his data surmised that when the light passed from air into glass, the angle of refraction was half again as great as the angle of incidence. Repeated experiments confirmed this *law*, if the angle of incidence, that is the angle between the entering beam of light and a line perpendicular to the surface at its point of entrance, did not exceed 30°. Still later Snell and Descartes discovered, by more careful experiments and more exact thinking, the present statement of the law that the sine of the angle of incidence bears a constant relation to the sine of the angle of refraction, which relation is always the same for any given medium; and again this statement of the law of refraction was at first tentatively held merely as a hypothesis, but was confirmed by re-

peated experiment. The law was now definite and exact.

Then, in 1690, Huygen's "Traité de la Lumière" was published in which he explained this, together with other laws and phenomena of light, on the basis of his wave theory. At first, this theory received scant consideration, for Newton's corpuscular theory had general credence, but as it was seen how well the theory explained refraction, dispersion, polarization and other light phenomena, it was generally adopted. Thus has scientific knowledge advanced from principles, expressive of relationships, to laws, in which the relationships were expressed with mathematical precision, to theories that give a basis for the understanding of many laws.

The labors of the alchemists had resulted in the discovery of a good many chemical substances and of methods for their preparation. Such knowledge was, however, a by-product of the main purposes of the alchemists. By the sixteenth century, such chemical substances and processes were becoming of sufficient value in medicine, industry and the arts to make the knowledge concerning them worthwhile for itself. Robert Boyle rejected the old Aristotelian notion of the four elements, earth, air, fire and water, and substituted the concept that an element is a substance that can not be further subdivided and that these elements unite to form compounds. It was not long before chemists began to wonder if there was any definite and fixed way in which these elements unite. They began to sense a problem and one with many practical bearings. For instance, in the reduction of iron ore, should the ore, the limestone and the charcoal be put into the furnace in definite proportions? If so, what were the proportions? To solve problems of this type, chemists began gradually to accumulate facts. Bergman found that one hundred parts by weight of silver precipitates out one hundred thirty-five parts by weight of mercury, from a neutral solution of the latter substance. Cavendish found that there was some sort of a definite relationship in the interaction of acids and bases. Richter showed that it always takes a definite amount of a given base to neutralize a definite amount of a given acid. This principle that chemical action goes on in perfectly definite ways was crystallized into the law of definite proportions of Proust and the law of multiple proportions of Dalton. At first, of course, these laws were proposed as hypotheses. It was only as they were substantiated by the numerous facts brought out by experiment that they advanced to the standing of proven laws. Then Dalton took a long step forward when he explained these laws on the basis of his atomic theory.

Long before the time of Gregor Mendel, facts concerning heredity had rendered clear to mankind the principle that there is a definite relationship between the characters of parents and of their offspring, but Mendel appreciated the need of discovering some exact statement of this relationship, a real law. He recognized that only when such a law was available could breeders proceed with any certainty to produce better plants and animals. It was this problem of the practical breeder that he perceived and clearly defined. So by extensive, purposeful experiments in crossing garden peas, he proceeded to collect facts. These he studied to find, if possible, some significant relationships. He analyzed the complex data, picked out the essentials and synthesized a new idea. He thought he found that one of a pair of antagonistic characters (like tallness and shortness of the vines) dominated in the children. And in the grandchildren there was a definite ratio of three individuals manifesting the dominant character to each one that showed the recessive. This tentative hypothesis was tested by addi-

tional crosses involving other characters. Tens of thousands of offspring were reared. The added facts confirmed the conclusion he had first reached. So he felt that the facts warranted the statement of his law as a well-reasoned judgment. Much later, by similar process of scientific thinking, came the theory of the gene to account for Mendel's law and its extension to the phenomena of linkage, factorial inheritance, etc.

Types of Reasoning in Science

As has been repeatedly pointed out, there are at least five types of reasoning in the inductive thought process; (a) the method of similarities, (b) of differences, (c) of similarities and differences, (d) of concomitant variation, (e) of residues. (Mill's "canons"—See his Logic Book III.)

(a) If, in a changing group of possible causes, one is constant and one effect is constant in a changing group of effects, that cause is the essential antecedent of the effect. Thus Koch found that no matter how variable in other particulars tuberculous patients might be, the tubercle bacilli were always present in their organs, and no matter how variable their later behavior might be, death from tuberculosis was the constant sequence. He therefore concluded that the tubercle bacillus was the cause of the disease.

(b) If, in a group of possible causes, one is always absent, and one effect in the group of effects is also always absent, the absent effect is the consequence of the absent cause. So Koch reasoned that since, when the tubercle bacillus was absent in an animal or a human, death with the characteristic symptoms of tuberculosis never ensued, the tubercle bacillus was the cause of the symptoms and the consequent death.

(c) Combination of these two lines of argument constitutes the method of similarities and differences. The combined method is evidently not always possible.

(d) In the method of concomitant variation, it is assumed that if one possible cause in a changing group is varied and one effect varies concomitantly, the two are related as cause and effect. Boyle found that increase in the pressure to which a given volume of gas was subjected was accompanied by a corresponding decrease in the volume of that gas and *vice versa*, that every decrease in pressure was accompanied by a corresponding increase in the gas volume. He, therefore, concluded that the change in the volume of the gas is caused by the change in the pressure to which it is subjected.

(e) If all the effects in a given group can be accounted for by causes known to be present, except one, and that one effect is accompanied by one cause, that cause is productive of the effect. Thus the irregularities of the movements of Uranus could not be all accounted for by the known attractions of the other heavenly bodies. It was necessary, therefore, to hypothecate the presence of an unknown planet to account for these irregularities. From these, its mass and position were calculated and the planet, Neptune, was discovered, located by reasoning on the method of residues.

Safeguards of the Elements in Scientific Thinking

(a) *Ideas of Accuracy*

It is very desirable to inculcate pupils with ideals of scientific accuracy. In the history of science there are many instances in which even the masters have failed because of their lack of accuracy or have succeeded because of their insistence upon it. When Kepler undertook to determine the form of the orbits of the planets, he based his work on the observations of Tycho Brahe who, for many years, had recorded the positions of the planets. It was because these observations were accurate and extensive that Kepler determined the orbits to be

ellipses and later discovered the laws of planetary movements.

De Saussure thought he saw the microscopic animalcules reproduce by fission and so reported the fact. But Ellis, an Englishman, denied this, claiming that the young came out of the body of the parent. He said he was able to see the children inside the parent and even the grandchildren inside the children. Spallanzani put a drop of broth swarming with infusoria on a glass slide; near it he put a drop of pure water. He connected the two drops by a tiny bridge by drawing the broth out with a fine brush until it connected with the drop of water. Under the lens he watched this bridge until he saw one animalcule swim over into the drop of water. He then wiped the bridge away and sucked the drop of water with its one animalcule up into a fine glass tube. He watched this one animal continuously, saw it divide and the two offspring redivide. This he did again and again until he was sure that de Saussure was right.

When Pasteur went down to Alais to study the silkworm disease that was destroying the silkworm industry of Southern France, he found that the silkworm moths and their eggs and even the worms had in them hordes of tiny globules. This was merely the confirmation of a discovery that had been made earlier by another student of the disease. Pasteur told the farmers to examine the fat under the skin of father and mother moths after the eggs were laid, and if none of these little globules were found in the fat, the eggs would be healthy and would hatch out into worms that would also be healthy. The farmers followed Pasteur's directions, but a great many of the worms still died of the disease. Pasteur had thought that if the moths were infected, the fat bodies would show the globules. His later and more accurate observations proved that it was necessary to examine the fluids from several parts of the moth's body, for the little living organism that caused the disease might be found in certain parts and not in others. It was inaccuracy that led to his early failure in directing the farmers how to combat the disease.

So in modern times we find Professor Michelson spending years in a series of experiments to determine the velocity of light, refining his experiments year after year so as to make the determination with exceeding accuracy. Dr. Paul R. Heyl, working at the United States Bureau of Standards, has just finished an accurate determination of the gravitational constant. Newton's Law states that the attraction of gravity increases with the mass of the attracting bodies and decreases as the distance between them becomes greater. If the figures representing the masses be multiplied together, the product divided by the distance and the quotient multiplied by the gravitational constant, an expression of the gravitational pull between the two bodies is obtained. Since it is important that this be determined with exactitude in mechanics, both terrestrial and celestial, this gravitational constant is an important factor. An Englishman, Nevil Maskelyne, tried to determine it in the eighteenth century by suspending a metal ball of known mass beside a mountain whose mass could be estimated. The metal ball is drawn out of plumb by the attraction of the mountain and by measuring the amount of this deflection, the gravitational constant was determined. The method was not an accurate one, however. The latter part of the same century, Henry Cavendish, also an Englishman, devised a more refined method. A light but rigid bar was fixed at its midpoint on top of one end of a vertical wire, the base of which was also firmly fixed. Small balls of equal mass were fixed to the end of the horizontal rod. Near these balls were

placed large metal spheres of known mass. The mutual attraction of the large spheres and the small ones tends to twist the vertical wire. A tiny mirror was fixed at the top of the wire so that a beam of light was reflected from it to the wall of the room. A very slight twist in the wire made a large displacement of the spot of light on the wall. It is this method that Dr. Heyl has also used with every precaution to measure the deflection with great exactitude. The figure obtained is now 6.664. Much of the rapid advance of science in the modern period is due to the invention of precision instruments that make accuracy possible, like the thermometer, galvanometer and spectroscope.

(b) *Observation must be Extensive*

Observations must also be extensive. The student must be aware of the danger of drawing conclusions from a single instance, or from a few instances. The term oxygen means "acid former" and for a long while it was thought that the combination of certain substances with oxygen produced acids and that acids were only so produced. Later, however, acids were discovered that contained no oxygen. The whole idea of the nature of the acid was, therefore, wrong in the time of Lavoisier, due to the fact that judgments were based on a limited number of cases.

William Smith was an English surveyor whose profession necessitated his traveling all over England. He was also interested in fossils and collected these in many localities and took careful notes on the character and relationships of the strata in which they occurred. It was these extensive observations that enabled him to see that strata with like fossils were formed contemporaneously and that the fossils in the strata could be used as guides in determining relative age of the deposits.

(c) *Observation under Varying Conditions*

Observations need to be made under a variety of conditions. Newton desired, if possible, to make a telescope free from chromatic aberration; that is, one in which the image would not be surrounded by a halo of color. He knew that light passing through a lens is broken up into its component colors just as it is in passing through a prism. He thought it might be possible by a combination of lenses to overcome this defect. To test the possibility of this, he put a glass prism in a prismatic vessel filled with a sugar of lead solution. The apex of the glass prism pointed in the opposite direction from the apex of the prismatic vessel. His idea was that one prism might undo the dispersive effect of the other. He found, however, that the light after passing through both prisms still showed color bands and concluded that the achromatic lens was impossible. If he had varied the condition, however, using a variety of solutions, he would have discovered that some solutions would correct the dispersive effect of the glass prism much more than others and might, then, have hoped to find one that would correct the trouble entirely. Due to this failure of his to vary the conditions under which he worked and due to the great weight of his authority, the discovery of the method of making the achromatic telescope lens was delayed for more than a century.

(d) *Picking out Essential Elements*

In facing a problematic situation it is necessary to analyze the elements involved and to pick out those that are essential in its solution. It is pathetic to see how the old medical men in the days before the discovery of the germ nature of disease were groping around in the dark trying to find the essential

elements in the problem of the cause of disease. It was thought that malaria was due to inhaling the damp night air of swampy regions. Typhoid fever was supposed to be due to decomposition of organic matter; thus the outbreak in New York late in the eighteenth century was thought to have been caused by a boatload of water-soaked coffee brought from Brazil and dumped on the wharf to rot. Wolf[1] relates that in a certain hospital in Dublin many deaths occurred among the patients located on the first floor of the hospital, while few died in the second floor ward. It was concluded that for some unknown reason the first floor was very unhealthful. One essential element in the situation had been overlooked, however. The hospital porter was in the habit of sending all patients upstairs who could walk up, while those who were too sick to climb the stairs were put in the ward on the first floor.

(e) *Importance of Dissimilarities*

The student of science must be aware of the danger of basing conclusions on similarities alone. Quite frequently it is the differences that are manifest that give a clue to the solution of the problem. Basing conclusions on similarities alone has led to many errors and is the basis of the well-known danger of reasoning by analogy. Familiar examples are the common notions that the whale is a fish, that a bat is a bird.

Sir Patrick Manson, usually regarded as the "father of tropical medicine," was in charge of a hospital in Formosa. While on leave of absence, he read of Lewis' discovery of the *filaria* worm in the blood of man. When, in 1875, he returned to China, he instructed two of his native helpers how to examine the blood of native patients for these worms. One of these, who was on duty by night, reported finding many worms, while the one on duty by day reported very few. It was this striking difference that made Manson think that the agency that transmits the worm from person to person was probably active by night and since the worm inhabits the blood, it was probably some bloodsucker. This made him suspicious of the mosquito. Examination of the mosquitoes found in the hospital wards confirmed his suspicion. It was the carrier of the filaria worms that caused elephantiasis.

Yet reasoning by analogy is safe if adequate experimental check is made on the conclusions. Franklin was struck by the similarities in the electrical discharge from a Leyden jar and lightning. Both gave light; both ran a crooked course; both made a crackling noise, destroyed life, were accompanied by a sulphurous smell. But he tested his hypothesis that they were the same by his famous kite experiment.

(f) *Exceptions Always Significant*

Exceptions to the general rule always need careful consideration. The old adage that the exception proves the rule uses the term "prove" in the sense of test. The exception tests the rule, and frequently strains it to the breaking point. When Bateson crossed two white-flowered sweet peas and obtained purple-flowered offspring, he discovered an exception to Mendel's Law that necessitated the modification of that law, well-known now as the factorial hypothesis. That same law was again under necessity of modification when the exceptional behavior of sex-linked characters was considered. The student of science must learn not to ignore exceptions, but to pay special attention to them.

(g) *Wide Range of Experience*

The value of a wide range of experience as a basis for selective recall is constantly evident in the history of

[1] Wolf, A., "The Essentials of Scientific Method." Macmillan.

science. Joseph Lister was a surgeon in the Edinburgh Infirmary when gangrene was rampant and septic poisoning killed a high percentage of the patients. In Munich it was estimated that eight out of ten people operated on died of gangrene. Lister knew that gangrene was a putrefaction of the flesh. The very odor in the hospitals was evidence of that. But what was the cause of the putrefaction? When a paper of Pasteur's fell into his hands, showing that putrefaction was caused by micro-organisms, Lister saw at once that gangrene was something that attacked the patient from outside and that it was not "in the blood" as was formerly supposed. He recalled that in the city of Carlisle the sewage was freed of its vile odor by mixing it with carbolic acid; presumably then the carbolic acid destroyed the germs of putrefaction which was going on in the sewage. It was this ability to cull out of his broad experience this incident, apparently entirely unrelated to hospital practice, which suggested that wounds be treated with carbolic acid. The suggestion led to his system of antiseptic surgery that reduced the death rate in hospitals amazingly, until it was a mere vestige of its former high figure.

A bit of experience, while out sailing, enabled James Bradley, professor at Oxford in the seventeenth century, to solve a perplexing problem in astronomy. Many of the stars seemed to shift their position about twenty seconds of arc every year. He could not see why. While sailing he noticed that the weather vane on the mast shifted its position each time the boat changed its course. He thought, at first, that the wind must be veering, but the boatman said the direction of the wind was constant, but the vane took a direction due to both wind and the direction of motion of the boat. Then Bradley saw that the apparent position of a star would be determined by the direction in which the light from the star was traveling and the direction and rate of motion of the earth in its orbit about the sun. At one part of the year the earth would be moving in the opposite direction from the direction it traveled six months earlier. Hence the apparent displacement.

(h) *Consider All Possible Hypotheses*

There is an excellent illustration of the necessity of considering all possible hypotheses in Spallanzani's experiments on spontaneous generation. Needham found that many tiny organisms appeared in mutton broth, even when the latter had been boiled and then kept in tightly-corked flasks. The same thing, he said, happened in a soup made of seeds like peas. Spallanzani, however, sealed the necks of his flasks in a flame, thinking that possibly the corks could not be set tightly enough to prevent micro-organisms in the dust of the air getting in. After the flasks were sealed he kept them and their contained soup in boiling water for an hour. When, days afterwards, these were opened and the soup examined, no living things were found. But Needham said that when soup was thus boiled for so long a time the "vegetative force" which it contained was destroyed. So Spallanzani boiled some of his soup for an hour, some for two hours, and put it into flasks whose necks were merely corked. He examined the contents of the flasks a few days later and found more of the micro-organisms in the soup that had been boiled two hours than in that which had been boiled only one. He also baked beans and peas until they were charred almost black, so as to destroy any "vegetative force" that they might contain, but soup made from these and allowed to stand yielded the living organisms, just as well as that from the fresh seeds. Again, however, Needham objected that the elasticity of

the air was destroyed in Spallanzani's flasks and that the organisms could not exist without normal elasticity. Spallanzani drew out the necks of the flasks in a hot flame without sealing them. He then put these flasks into boiling water and left them for an hour or more. Then when they had cooled, he sealed the tiny opening at the tip. When these flasks were opened in due course of time, no living organisms were found in the broth, although the air pressure in the flask was greater than that outside, for when the tip of the flask was broken, a flame placed near the opening was blown away by the escaping air. One hypothesis after another had to be considered and each disproven before Spallanzani felt convinced that there was no such thing as spontaneous generation. One who is familiar with the history of this idea knows that after the time of Spallanzani, other hypotheses had also to be considered and disproven.

(i) *Test the Inferences from Hypotheses*

Hypotheses must be verified experimentally always, if possible. A chance experience of Oersted's (1819) showed him that a current of electricity passing through a wire held parallel to and over a compass needle causes the needle to be deflected. Argo found that a wire through which a current is passing attracts iron filings. Possibly it is to be considered a magnet. Two such wires, then, Ampère thought, should attract each other like magnets. He confirmed his inference by experiment. Then Michael Faraday said that if the current in the wire makes the magnetic needle move, a moving magnet should produce a current in a nearby wire. This inference he tested and found true.

Heat was, by the earlier physicists, thought to be a material substance, caloric, that was taken on when a body became hot and given off when it cooled. Rumford inferred then that a body should gain in weight when heated. He weighed a cannon that was to be bored and the boring tool. They were weighed again when the boring was done. Both cannon and tool were made very hot by the boring, but neither had gained in weight. In this case the caloric hypothesis was not verified and Rumford concluded it was untenable.

(j) *Allow Only One Variable*

It is exceedingly important that in all experiments to test the inferences from an hypothesis or for that matter in any experiments, all factors be kept constant except the one variable whose effect is being tested. Some of Pasteur's opponents, unconvinced that the bacteria were the cause of anthrax, drew blood from a sheep that had died of the disease and injected some of this into rabbits. These rabbits died promptly, although no anthrax bacteria were to be found in their bodies, showing, to their way of thinking, that the bacteria had nothing to do with the death of the sheep. But they had waited so long before introducing the sheep's blood into the rabbit's that putrefactive changes had developed poisons that killed the rabbits before the anthrax germs had a chance to multiply. A whole set of new variables had arisen that vitiated the results of their experiments.

Falk in his "Principles of Vital Statistics" quotes an experience of Dr. Vaughan that shows to what ridiculous conclusions one may be led by using data involving a number of variables. "In 1888, at an international medical congress, I ventured to offer a paper in which I suggested that summer diarrheas of infancy might be due to poisonous milk. When the paper was opened for discussion a learned, elderly man arose, and after making some feeble complimentary remarks directed to the writer, proceeded to demolish all his claims, and finally he suggested that the

high infantile mortality, which was becoming greater and greater every year, could be attributed to the more common use of the baby perambulator because, he said, and no one could deny the statement, that the death-rate among children in this country had increased since the baby cab had come into use. When I arose to close the discussion, I said that I would withdraw all that I had claimed concerning poisonous milk, that the argument adduced by my critic could not be contradicted, but I would suggest that the high infantile mortality was due to the fact that we were more in the habit of carrying umbrellas than our ancestors, or that possibly it might be due to the fact that we eat more tomatoes than our grandfathers did."

(k) *Skill in arranging Data*

To arrange data and the arguments based upon them in such cogent form that the conclusions are most readily discerned is one of the eminently desirable skills to be achieved through scientific studies. Numerous recent studies have shown that both in individual laboratory work and in demonstrations from the instructor's desk, students are woefully inept in drawing conclusions from the data presented. They know reasonably well how the experiment was set up and what happened in it, but the meaning of it is obscure. They have not been forced to state the evidence so cogently that its significance is apparent. The experiments in science classes may easily degenerate into mere "busy work" unless the teacher holds pupils rigidly to the necessary reasoning that makes the experiment meaningful and transforms experiences into real science.

To quote samples would occupy space unnecessarily. To cite them is sufficient. Read, for instance, Lyell's "Principles of Geology" to see how cogently he states his facts and his arguments to show that geological processes have not been primarily catastrophic, but are ever operating slowly but surely, the same yesterday, to-day, and forever, to produce geological changes. So he transformed the old Wernerian geology into the modern science. Or, again, read Agassiz's "Studies on Glaciers" to see how he marshals his facts and his arguments to prove the part played by these agencies in transforming the physiographic features of the temperate continental areas. Read Darwin's epoch-making "Origin of the Species" and you will appreciate another fine example of the patient but masterly mustering of an array of data in orderly and potent form for the successful attack on a difficult problem. The masters of science have been masterful because they were experts in this art of the cogent arrangement of facts and arguments. The beginner needs much drill in this same art. It is one of the rare opportunities of science instruction.

(l, m) *Pertinency and Adequacy of Data*

The student of science must constantly be trained to pass critical judgment on the pertinency and adequacy of the data he is using. Robert Boyle (1627–1691) realized in a measure at least how essential it is to judge the pertinency of the data bearing on a problem. He severely criticizes the old alchemists for their impertinency. He writes in "The Sceptical Chymist": "If judicious men, skilled in chymical affairs, shall agree to write clearly and plainly of them, and thereby keep men from being stunned, as it were, or imposed upon by dark and empty words, 'tis to be hoped that these men (the Alchemists) finding that they can no longer write impertinently and absurdly, without being laughed at for doing so, will be reduced either to write nothing, or books that may teach us something, and not rob men, as formerly, of invaluable time; and so ceas-

ing to trouble the world with riddles or impertinencies, we shall either by their books receive an advantage, or by their silence escape an inconvenience." Many of the alchemists posed as magicians, and alchemy was allied in the popular mind with the black art. The naive beliefs of these pseudo-scientists warranted Boyle's criticism. How uncritical they were of either the pertinency or the adequacy of the data on which such beliefs rested is apparent from the following typical remedy of these magicians. When a goat sneezes violently some of the worms are expelled from its brains into its nostrils. These are to be carefully extracted, placed in a cloth without allowing them to touch the ground, then three of them are to be tied in the thin skin of a black sheep and worn around the patient's neck. This is a sure cure for epilepsy.

A sapphire was supposed to nourish the body. The wearer could neither be harmed by fraud, nor envy, nor could he be moved by terror. It would free a prisoner who wore it. It helped in attaining answers to prayer. It healed ulcers, stopped headache, cured diseases of the eyes and reduced fever.

One realizes how essential it is to be ever critical of the adequacy of the data on which conclusions are based, when he sees the many, many errors into which the older scientists were perpetually falling because the data at their command were insufficient. The old Ptolemaic cosmography held sway for many centuries with the earth as the center of the universe and the numerous epicycles thrown in to the orbits of the planets to explain apparent irregularities in their movements. This was in spite of the fact that Pythagoras and his followers had earlier proposed the modern system. The crucial data were not forthcoming until the days of Galileo and Tycho Brahe to make the Ptolemaic system untenable. The pathway of scientific advance is so littered with the wrecks of discarded ideas and discredited theories that it behooves the science teacher to cultivate in pupils a critical attitude on the adequacy of the data he is examining. There is no greater danger than a too ready scientific credulity. The students who may pick the flaws in our present day scientific notions are in training in our schools to-day. They need to be alert to the inadequacy of the data on which we are basing some erroneous conclusions. Only a blind optimist could hope there were none such.

(n) *The Unprejudiced Attitude*

The judgments passed by the scientist must be unprejudiced, that is, he must free himself from preconceived notions and reach his conclusions on the basis of the evidence in hand. For a century before Priestley's day, burning had been explained as the process of giving off a principle called phlogiston. If a substance would not burn, it was said to be already "dephlogisticated." Priestley discovered oxygen. He prepared it by heating the red oxide of mercury, then called red calx of mercury, and collecting the gas over a pneumatic trough. The new gas would not burn, so he called it "dephlogisticated" air. He showed that this "air" was necessary to combustion and to respiration. He visited Lavoisier in France and showed him his method of making the gas. Over a century before Jean Ray had shown that the calx of a metal is heavier than the metal, and Lavoisier showed that when a metal burns (or oxidizes) to form the calx, the latter is heavier than the metal by an amount equivalent to the weight lost by the air. He further showed that the air also loses in the process the power to support combustion. Lavoisier concluded rightly that the burning is a union of the burned substance with oxygen as he called

Priestley's "dephlogisticated air." But Priestley was so saturated with the phlogiston notion that he could not free himself from it, his judgment was prejudiced, and he remained to the end of his days a "phlogistonist."

(o) *Impersonal Judgment*

Judgment must be objective, impersonal. The scientist must free himself from personal bias and base his conclusions on the evidence in hand in spite of personal preferences. Humphry Davy, experimenting on a rabbit, and then on himself, discovered that nitrous oxide or laughing gas produced momentary insensibility when inhaled. Michael Faraday, later, found that sulphuric ether would accomplish the same result. In 1844, Dr. Horace Wells, of Hartford, Connecticut, painlessly pulled a tooth with the patient under the influence of nitrous oxide. In 1846, Dr. Marcy, of Boston, removed a tumor while the patient was under ether. In 1847, Dr. J. Y. Simpson used ether and chloroform to relieve suffering in childbirth and persisted in spite of tremendous opposition, based on the biblical curse pronounced on Eve. One would think that so great a scientist as Dr. Simpson with his background of experience would be open-minded on a scientific problem. Yet he opposed Lister's method of antiseptic surgery, biased against Lister apparently because Lister had devised a method of tying blood vessels, in operations, with gut, which replaced Simpson's method of closing the vessels with needle-like instruments. Simpson could not free himself from personal animosities and judge solely on objective evidence.

(p) *Suspended Judgment*

Finally the scientist must hold his judgment in suspense until the evidence is overwhelming. In a letter to Asa Gray, under date of July 20th, 1856, Charles Darwin wrote: "Nineteen years ago it occurred to me that whilst otherwise employed on natural history, I might perhaps do good, if I noted any sorts of facts bearing on the question of the origin of species, and this I have since been doing. Either species have been independently created or they have descended from other species, like varieties from species. I think it can be shown to be probable that man gets his most distinct varieties by preserving such as arise best worth keeping, and destroying the others. . . . I assume that species arise like our domestic varieties. . . . I believe I see my way pretty clearly on the means used by nature to change her species and adapt them to the wondrous and exquisitely beautiful contingencies to which every living being is exposed." This theory of the origin of species was not published until 1859, three years later. For nineteen years judgment had been suspended while evidence accumulated. Now in 1856 he sees his way pretty clearly; such caution is truly scientific.

ANIMAL HUSBANDRY AND WAR

By SYDNEY HILLYARD

In the breeding of animals the work of one man is not enough to furnish more than a mere foundation upon which his sons, grandsons and great-grandsons must build. The work of selection—the picking out of the strongest or fastest horse, the heaviest wooled sheep, the cow with the most or the richest milk—must continue for generations unbroken, or we can quickly have a retrogression, a devolution back to the wild stock—a much easier thing to get than an evolution toward the perfect specimen that has become so necessary to modern life.

Thousands of English sheep farmers, unknown and unsung, from Edward the Sixth to Edward the Seventh, a matter of three hundred and fifty years, have patiently and persistently picked out their best rams or bought better ones, and have raised the net value of the sheep of their country by a slightly thicker wool or a shade heavier mutton. This is all there is to breeding, but it takes two things—time and security. An army turned loose in a sheep country for a winter will eat the sheep or drive them off and the farmer has to begin a century's breeding all over again with runts, where his great-grandfather left off. And this is the case whether it is your own army that is encamped, fighting or maneuvering over your country or your enemy's. This was very well shown in the Hundred Years War between England and France and in the Thirty Years War that was fought all over Germany.

The English archers who fought with the longbow at Crecy, Agincourt and Poitiers did not care how many or what kind of sheep were left in France after the army was fed. The hide of an extra-fine fleeced ewe would make a pillow, a patch or a washrag. The mutton of an oversize tup filled the more mess cans. The soldiers of Gustavus Adolphus or of Wallenstein, whether Protestant or Catholic, ate about the same amount, and being in Germany, they ate German sheep. At the end of thirty years there were so few cattle and sheep left in Germany that the starving peasantry were eating human flesh. It takes a century to get a breed of animals well started; it takes a week to wipe it out. On the continent of Europe this has happened again and again, until one wonders how anything larger than a performing flea with a lusty jump is left alive.

And this brings us to the following question: Why have nearly all the great breeds of domestic animals that are now scattered all over the earth, the horses, cattle, sheep, hogs, been originated and perfected in England? Why not elsewhere? If it takes three centuries of careful breeding, watching and protection to raise a perfect horse that a war can wipe out in three hours, why have so many breeds been perfected in England and so few elsewhere? Let us see how England stands in this matter of animal breeds, and then let us ask how this has come about, and what it has to do with war and disarmament. First, let us see if there be one country which stands out above all others in the initiation and consummation of bred stock and then let us deduce a theory to fit the demonstrated facts.

Let us take horses. The great Shire, Clyde and Suffolk heavy horses are the most widespread draft horses of the world. They haul the beer-wagons of

Berlin, the water-wagons of New York and the plows of Alberta, Queensland and the Argentine. The Shire, with his shaggy legs, the Clyde with his round belly, the Suffolk with his thick neck, each took many lifetimes of farmers to bring him from runthood to drafthood, from a rangy scarecrow to a mastodon of one ton. So with the English thoroughbred, the fastest of living animals. It is literally running circles all round the globe. You can lose a dollar on him as easily at Saratoga as at Sydney or Epsom Flats.

The word "Shire" in connection with horses was first used in the statutes of Henry VIII, in 1530. Under various names—the War Horse, the Great Horse, the Old English Black Horse, the Shire Horse—this breed has for centuries been cultivated in the rich fen lands of Lincolnshire and Cambridgeshire. He is the largest of horses. The thoroughbred comes later, beginning probably with "Markham's Arabian" in 1616. Three other horses followed, Byerly Turk, Darley Arabian and Godolphin Barb, and from these animals all the race horses of to-day have descended. From Henry the Eighth, he of the many wives, and Charles the Second, when America was getting nicely started, to this day, these, the largest and the fastest horses, have been patiently nursed.

The American standard trotter dates from the Darley Arabian through the Hackney and Norfolk trotters. Its career is similar to that of the thoroughbred and for the same reasons.

As with the horse so it is with the cow; both with the big beef breeds and the little dairy breeds. The red-faced Durham ox and the white-faced Hereford, the Devon, the Angus and many other beef steers are British stock, while the milkers, the Jersey and Guernsey, are from the Channel Islands.

The Brown Swiss and the Simmenthaler are continental cows and have come to maturity apparently for the same reason as have the world-wide English breeds. They have been raised in the Swiss mountains, exposed to storms and snow but sheltered from soldiers.

The first scientific breeder of cattle was Robert Bakewell, of Loughborough, Leicester, England. This man made thousands of pounds out of his bred stock. The Collings brothers followed him and started the Durham cattle with "Hubback" in 1777. The Durham is the same thing as the Shorthorn, now the most widely spread of all cattle. One Tompkins followed Collings with the Hereford, and then a Mr. Watson with the Angus, and a John Ellman, who founded the Southdown. These people did not invent the cow; they inventoried her, started her on the narrow path and made a doomsday book in which to record her. And she has nobly responded. The Chicago stockyards demonstrate this.

"What shall we debate?" was the question in the good old days back on the farm at the first literary and debating society's meeting in November.

"Which is more useful, the horse or the cow," came the invariable answer. In the ranch country the horse won the decision; in the farm settlements, the cow. But whichsoever way the embattled farmers voted, it remained proved that a team consisting of a horse and a cow had helped haul civilization for a long distance.

An Englishman and an Irishman may differ as to some things, but they see with one eye when it comes to a hog, and the American is there with them. In fact America really leads the field. But it is enough for our story that the Berkshire, the Yorkshire, Tamworths and other breeds were British, with the American Duroes and Chesters descended from the same source. There is no continental hog worth spearing. Without England and America the hog

would be a razorback in the forest, useless to himself or to any one else.

England has done wonders in chickens with the Brahmas, the Plymouth Rocks, Orpingtons and others too numerous and too noisy to mention, but here again the American hen has it. The Yankee rooster has a right to crow over all comers for size and over all scrappers except the English fighting cocks. Outside of the Anglo-American hen there is not very much to write home about. The campfire kettle is hard on the poultry yard; always has been—and always will be.

The goat has had the best chance of them all at self-development. He started first. All the wandering sheiks from Abraham down had goats, but it is probable that the simple-minded nannie in your vacant lot is little better than those that Isaac milked. The Angora goat is the product of the mountains of Asia Minor and the Caucasus and of other secluded mountain districts, as the brown Saanen and the white Toggenbung of Switzerland. England and the United States have never tackled goat-breeding. The goat has had to live in fastnesses where he could jump down a precipice when a foraging party showed up. Had he found favor with a breeding nation what might he not have been?

But it is in sheep that the tight little island has simply done it all. It has been "Let George do it," and in truth it is perhaps in the reigns of the four Georges more than at any time in eight hundred years that English sheep rose to supremacy.

There are a dozen major breeds of sheep from the English and Scottish counties which cover the hills of Christendom and the valleys of heathendom. Such are the Cheviots, the Oxfords, the Southdowns, the Shropshires, and others. There were no other sheep until Vermont, Australia and New Zealand developed the modern Merino.

All the mutton sheep are English.

Now we can carry the argument a step further. We find that war destroys domestic animals; we find that the principal animal breeds were produced in England. Why has England been able to do it?

Because of the English Channel.

That strip of water but twenty miles wide has done it. It is narrow, to be sure, but enough to keep the restless armies of continental Europe off the island since 1066. It was enough to keep England free from invasion for eight hundred years, while armies, including English armies, were tramping over Europe, eating and destroying the cattle, sheep and goats and using up the horses in their cavalry. Poland, Germany, Austria, Italy and France have had enough wars to knock out each and every attempt at animal breeding as fast as it was made. It is a wonder they have any animals at all.

Almost every European government has at one time or another tried to get animal breeding going except that of England. The English government alone seems to take no interest in it, and there alone has it been a complete success. The English farmer was left in peace by the armies, with a couple of civil wars for exceptions, to improve his sheep generation after generation, century after century, with the result described. Had a successful invasion of England say, by Spain in Elizabeth's time, or by France in Anne's time, or by Germany in Victoria's time, swept all over the country where would the thoroughbred horses be? Where would the Cotswold sheep be? Where, the Durham cattle? Thus went the continental animals—to carry the cavalry into battle and to feed the infantry after it.

"The Kaiser had the finest of the old English estates already parceled out among his favorites before the war started," said an Englishman to the

writer. "One of his sons was to have the seat of the Dukes of Portland." Just how true this is may be a question, but another question is, how many prize cattle would be left on the estates of England by the time Hindenburg and Ludendorff had got themselves into secure possession of them?

"There will be precious few Englishmen left alive to see it," said a British officer when the talk veered to what Germany would do with Britain in the event of occupation. If there would be precious few Englishmen left how many English thoroughbreds would there be? Answer: None.

During the Spanish invasion of the Low Countries the Dutch cattle were raised only in Schleswig. The Spanish armies destroyed them elsewhere. In 1786 the Germans imported some merino sheep that the French government had introduced from Spain and had established on a government farm near Paris. Something prevented the continuous development of these sheep, the kind of development that has taken place in America and Australia, and that something is in part war. In the latter part of the seventeenth century the French government began the systematic development of stallions in the vicinity of Paris in the province of Normandy. The French have met with success in the Percheron horse, a draft animal much favored in America. A professor of agriculture informed the writer that he attributed survival of this horse to the fact that it was bred in that part of France, La Perche, which has been most free from invading hosts of all the country. The snow-white Emden goose and the Holstein-Friesian cattle originated in the lowlands adjacent to the North Sea. East, west, and south of them are rivers and turf bogs. No armies, the writer is informed, have ever maneuvered across that territory.

The Belgians have a fine draft horse, but we are informed that this last war has left the United States in possession of all the best of the breed. Similarly, the Russian government in 1777 started a stud of the Orloff horse. It is said that few of the finest of these horses will have survived the last six years of war. It would be nothing less than a miracle if they could, and animals aren't saved by miracles—at least not in wartime.

It is true that the opposite side of the case can be argued at least as regards the horse. The French Coach Horse, the German Coach, and other continental saddle and driving horses are the result of various governments having selected and bred horses for cavalry. Yet this can apply to the breeding situation in only a limited way; it is true only of horses and to some extent of mules and applies only to a certain kind of horse. Once the army is supplied, the government's interest stops. All credit is due to the continental coach horse as a product of war, but it must not be forgotten that these very coach horses are used to kill each other on the battlefields, and to kill off other animals, so that the better the war horses the better foraging the cavalry can do and the more lambs and chickens they can gather in for the evening soup kettle.

Governments that breed men and animals for war are primarily interested in war. If there is anything that the World War has shown it is that the governments of Europe would sacrifice everything to win the war. The three kaisers now unhorsed would and did allow the war to go on until the resources of their peoples were exhausted—that is to say that the Prussian kaiser was willing to allow his own people to be destroyed rather than resign and lose his own crown and honor. The raising of horses by such people is not an asset in animal breeding; it is a liability. Governments that will stand by and see their race destroyed rather than their own personal

pride and power, are not animal breeders; the only creatures in their stock registry are the four horses of the Apocalypse.

The United States will be the nursery for the great breeds of the future. One hundred and twenty-five thousand dollars has been paid in this country for a single bull—the world's record for dairy animals. The American wool sheep, the American hog, the American milch cow now lead the world, and we are rapidly coming up in other breeds. There is no knowing what can be done if no armies devastate the farms and no poison gas murders our animals. But let us have peace. We have heard the call of the wild, the call of the carpenter, the call of the cities, and several other calls, now let us hear the call of the cow.

In "The Next War" Will Irwin has shown what the effect of airship, gas and poison may be on humanity. What will their effect be on the priceless breeding stocks? Will not humanity, for its immediate preservation, be compelled to sacrifice, to consume, whatever of its best animals the armies and artillery have left behind, if they leave any? Has this not already taken place in Poland and Russia and Serbia?

America is to-day the capital of the financial world. It is also becoming the capital of the animal-breeding world. If peace, on one little island, has brought forth these splendid breeds of animals that have served the world for centuries, what may it not achieve on this great continent if no recurring animal slaughters prevent? The horse, the cow, the hog and the sheep all call for disarmament.

Let us have peace.

JOHN LINING, AN EARLY AMERICAN SCIENTIST

By FRANKLIN C. BING

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ALMOST two hundred years ago there emigrated to this country a Scotch youth of twenty-two, named John Lining. He settled in Charleston, then called Charles-Town, in the Colony of South Carolina, and there practised medicine for thirty years until his death in 1760. Although he was an outstanding figure in the history of early American science there remains but one very brief biographical account of him, that by David Ramsay.[1] He was educated in Scotland and held the degree of Doctor of Medicine, probably, according to Dr. Wilson,[2] from the University of Edinburgh. Details of Dr. Lining's entire life that remain to us are very scanty. He had a fairly large practice, it is said, and enjoyed considerable renown for his scientific attainments. He is always referred to as "the celebrated Dr. Lining" or "the ingenious Dr. Lining" by contemporary writers. To him we owe the earliest experiments on metabolism made in this country. The first description of the symptoms of yellow fever that came from America was in a letter written by him to the professor of medicine at the University of Edinburgh. He even experimented with electrical phenomena and communicated with his famous colonial contemporary, Benjamin Franklin, upon this subject. Lining seems to have corresponded extensively and it is from those letters published in the Transactions of the Royal Society of London and in a publication of a Medical Society of Edinburgh that we obtain our knowledge of the work of this active and versatile investigator.

His experiments upon metabolism were the result of an effort to ascertain the relationship, if any, between weather conditions and epidemic diseases. This was the time of sweeping epidemics such as practically are unheard of to-day. Two years before his arrival in Charles-Town the inhabitants of that city had been afflicted by an epidemic of yellow fever. This malady occurred again in 1732, and it was then that Lining obtained his first experience with this disease. It was observed that yellow fever, like some other diseases, occurred only in the summer and lasted only until cold weather set in. Building upon this fact, Lining began making and recording systematic observations on the weather, starting in 1738 and continuing for several years. During the year of 1740 he made in addition measurements of his own metabolism, these measurements being made in a regular fashion every day for an entire year.[3] The object of this extended experiment is best stated in Lining's own words, as given in the preliminary report, made after observations extending over several months:

"What first induced me," he says, "to enter upon this Course, was, that I might experimentally discover the Influences of our different Seasons upon the Human Body; by which I might arrive at some more certain Knowledge of the Causes of our epidemic Diseases, which as regularly return at their stated Seasons, as a good Clock strikes Twelve when the Sun is in the

[1] Ramsay, David. "The history of South Carolina." Vol. 2 (1808).

[2] Personal communication from Dr. Robert Wilson, of Charleston, S. C., to whom I am indebted for first interesting me in the history of early American science.

[3] Lining, J. Metabolism Experiments. *Trans. Roy. Soc. 42*, 49 (1743). Ibid. *43*, 318, (1745).

Meridian; and therefore must proceed from some general Cause operating uniformly in the returning different Seasons."

To study the weather conditions from day to day Lining had a complete set of meteorological instruments. A whipcord hygroscope was used for recording the relative humidity of the air. Lining recorded the appearance of the sky, whether it were clear or cloudy, and the amount of cloudiness. He made an instrument, which he did not describe, for ascertaining the amount of rainfall. He recorded also the force of the wind each day, remarking that this factor played an important part in cooling the body by evaporation of the perspiration. For this measurement he had no instrument, but judged by the senses. He used Fahrenheit's thermometer to record temperatures, and in addition, a peculiar type of thermometer made by a Thomas Heath, of London, which was divided into ninety equal parts, 65 being freezing, and 49 temperate. The modern Centigrade thermometer was, of course, unknown in those early days. The difficulties of experimental work scarcely can be appreciated, when even the commonest instruments of the modern laboratory were either not yet developed, or had to be improvised by the experimenter himself. A contemporary of Dr. Lining calibrated his own thermometer by measuring off the inches between the lower fixed point, the temperature of melting ice, and the upper, the temperature under the armpit of "a man in health."

For studying the effects of the environmental conditions upon the human body, Lining made careful measurements upon himself. Each day he would record his weight upon arising, and also before retiring at night. At these same times he would ascertain and record his pulse rate. All the food that he ate during the course of the day was weighed, and all the liquids that he drank were measured. Each day he would record the amount of his urine, the weight of his solid excreta, and the quantity of perspiration given off. The latter figure was obtained by carefully weighing his dry clothes before wearing them, and also after taking them off. The increase in weight of the clothes was recorded as the amount of perspiration. During the summer months these weighings had to be made several times in a day.

"Thus," says he, "have I now spent near One Year, with no small Labour, Confinement, and Expence in the Loss of Practice, in making these Experiments and Calculations; and if they will be of any Service to Mankind . . . shall then obtain all I had in View, in entering upon the Course."

His second paper concluded the data for the year and tabulated it. It is interesting to observe that he contemplated performing blood tests upon himself, but was forced to refrain from so doing because of the crudeness of the available methods of that day. He states:

That I may be furnished with as many Data as possible, I propose to take the specific gravity of the Cruor, of the Serum, and Crassamentum of the Blood, in different Diseases, and in their several Stadia, by a very nice hydrostatic Balance, made by Mr. Jackson. But this indeed is attended with greater Difficulties than I was at first apprised of, for the Experiment requires a greater Quantity of Blood than can at all times be safely taken away; and Rain-water, with which the specific Gravity of the Blood is compared, I have found, by repeated Experiments, to lose about 3/512 Parts of a Grain for each Degree of Heat by Fahrenheit's Thermometer; and Oil of Turpentine, in which the Crassamentum is weighed, loses much more of its specific Gravity.

Present day readers may well remark at the painstaking nicety of Lining's experimental technique, considering the date at which it was done. The spirit of his experimental procedure throughout is thoroughly modern.

The data accumulated by Lining showed conclusively that the volume of the urine is roughly inversely proportional to the amount of perspiration; the amount of perspiration being greatest in the hot months of summer and

least in the winter, and the volume of the kidney secretion being, conversely, greatest in winter and least in summer. Dr. Lining was content to give his data and his protocols. Other men made use of his information, and sometimes constructed fantastic theories to account for his results. Thus, we find that Dr. George Milligen[4] divided acute fevers into those of the hot months and those of the winter months, and gave a very involved and hypothetical explanation of their production as a result of weather conditions.

Patrick Ker,[5] a medical student at the University of Edinburgh, in 1746 attempted to correlate the occurrence of several diseases with the weather conditions in Edinburgh and in nearby towns, but his work was mainly statistical rather than experimental. The spirit of Lining's work, on the other hand, might well serve as a model for students pursuing similar investigations to-day. He formulated his hypotheses clearly and tested them out fully and carefully, making use of the best available instruments of his day. He checked his methods carefully, and was not loath to criticize any defects of his own experimental technique. That all this was done by a man working alone and unaided in a country miles away from the great intellectual centers of the world is all the more remarkable. Two recent investigators[6] in the field of "insensible perspiration," writing of the history of the determination of the amount of perspiration, have expressed amazement at the patient thoroughness of Dr. Lining's experimental work. For years these observations of this little known American investigator remained the most complete and extensive on record.

Dr. Lining extended his meteorological observations over several years and these accounts of Charles-Town weather were published in the Transactions of the Royal Society.[7] Dr. Lionel Chalmers[8] continued these observations later, from 1750 to 1759, and when the Medical Society of South Carolina was formed such observations were made as a matter of routine, beginning in 1791.

Dr. Lining also is the author of the first accurate account of yellow fever that reached European centers from this continent.[9] It is in the form of a letter addressed to Doctor Robert Whytt, Professor of Medicine in the University of Edinburgh. It is essentially a history of the yellow fever as it appeared in Charles-Town in 1748. "In this history," says the author, "I have confined myself to a faithful narration of facts, and have avoided any physical inquiry into the causes of the several symptoms of this disease . . . " Dr. John B. Beck,[10] as late as 1842, stated that this account "stands to this day unrivalled for the general accuracy and minuteness of its description." Doctor Lining, however, believed that the disease was imported and contagious, and it is interesting to note that for many years afterwards the laws of South Carolina guarded against it as such.

About this time the attention of many men was directed towards electrical phenomena. Benjamin Franklin had

[4] Milligen, George. "A short Description of the Province of South Carolina." London. (1770).

[5] Ker, Patrick. Weather and Epidemic Diseases. In Lewis, Condensed Volume of Medical Essays and Observations, published by a Society in Edinburgh. Page 77. London (1746).

[6] Benedict, F. G., and H. F. Root. Insensible Perspiration. *Arch. Int. Med. 38*, 1 (1926).

[7] Lining, J. Meteorological Data. No. 487, *Trans. Roy. Soc.* Ibid. *48*, I, 285 (1754).

[8] Chalmers, Lionel. "An Account of the Weather and Diseases of South Carolina." London (1776).

[9] Lining, J. "Essay on Yellow Fever." Supplement to Chisolm, Colin: "An Essay on the Malignant Pestilential Fever." Philadelphia (1799). Originally published in Edinburgh. Essays and Obs. *2*, 370 (1753).

[10] Beck, John B. Annual Presidential Address delivered before the Medical Society of New York. February 1, 1842.

already published his famous Treatise on Electricity, and in 1752 he wrote an account of his famous kite experiment.[11] Lining is said to have communicated with Franklin, and is known to have repeated some of his electrical experiments. An account of several kite experiments made by him is given in a letter sent in answer to queries made by a Charles Pinckney, of London.[12] Mr. Pinckney wished to know more about Dr. Lining's experiments, and particularly whether any danger was attendant upon performing them. A Professor Richman in Petersburg had been struck by lightning and killed while performing electrical experiments, and Dr. Lining's correspondent wanted to know the reasons for this unfortunate mishap. It seems that Professor Richman had lost his life during the summer of 1753 as he was observing the effects of lightning upon a "gnomon," or kind of device for measuring the magnitude of an electrical charge. Lining astutely inquired in return for more details about the apparatus used by Richman and also asked whether the iron rod by which the lightning was conducted to the instrument had any connection with the earth. It developed that Professor Richman's apparatus was connected directly with a lightning rod at the time when he performed the experiment, and that the lightning rod had no other connection with the ground.

A few years later, in 1760, Dr. Lining died at the early age of fifty-two. In that year an epidemic of small-pox visited Charles-Town and nine hundred and forty persons died of it, whereas but eighty-seven died of all other diseases combined. Whether Dr. Lining succumbed to this malady or not the available records do not state. His fame, however, long survived him. To-day he is worthy of recognition as one of the early scientific investigators of this country, and as a man who, with the same actuating motives of the best scientists of to-day, worked under difficulties that to the ordinary individual would have been well-nigh insurmountable.

[11] Franklin, B. Kite Experiment. *Trans. Roy. Soc. 47*, 565 (1752).

[12] Lining, J. Kite Experiment. *Trans. Roy. Soc. 48*, II, 757 (1754).

A WINTER SLEDGING EXPEDITION ON THE INLAND ICE OF GREENLAND

By HELGE BANGSTED

UNIVERSITY OF MICHIGAN GREENLAND EXPEDITION, HOLSTENSBORG, GREENLAND

Narrative of Journey

In the winter of 1925–1926 I undertook a sledging expedition over the Greenland inland ice from a base at Umanak, a northern colony of the West Coast in latitude seventy degrees north. This journey was undertaken without any special preparation, for it had been my intention to go as far north as Cape York; but I was not permitted to proceed beyond the Umanak district because of an epidemic which had broken out among the children of the northern district, and so my plans had to be changed.

I set out from Umanak near the end of January with two companions, Georg Strang, a moving picture operator, and an Eskimo, Kalepatuk. Our equipment we carried on two sleds, my own with a team of ten dogs, and one of twelve dogs owned by Kalepatuk. At the village of Ikerasak (the narrow sound), 40 kilometers to the south-eastward of Umanak, I was joined by two Eskimos with dogs and sled, and from there, on February 3, we started on our long journey which was the first ever to be made in midwinter over the inland-ice of Greenland.

As already mentioned, I had on leaving Copenhagen in August no intention of making any sledge trip over the inland-ice, and for this reason I had not brought with me the instruments which would have been desirable. I had with me, however, an alcohol compass, some alcohol thermometers for measurement of low temperatures, a small aneroid barometer, and a hodometer or sledmeter constructed from an old bicycle wheel with its attached cyclometer.

From Ikerasak we took our course over the sea-ice to the mainland at Kekertak, about ten kilometers to the westward of the foot of the Great Karajak Glacier, near which had been from 1891 to 1893 the base of the German Greenland Expedition under Professor Erich von Drygalski (see Fig. 1). The sea-ice we found very rough and hummocky, and it took us two days to cover the twenty kilometers between Ikerasak and Kekertak. Fortunately the weather was fine and the air very cold.

At Kekertak we encountered new difficulties in ascending the course of one of those rare rivers for Greenland which persist throughout the winter, and as a consequence by freezing solid to the bottom, they flood the surface and again freeze at the top so as to produce the troublesome "*sersinek* ice" (the ice which grows wider).[1] This surface ice is often so thin that sled, dogs and men all break through and have a bad time with the icy water and the low air temperatures.

After two days of traveling in the *sersinek* ice we left the river and now took our course through the high mountain country up to Isortok. Here the inland-ice comes down as a long smooth tongue up which traveling should not be difficult.

Before leaving Umanak the white residents, and the Greenlanders as well, had all assured me that it was an impossibility to travel on the inland-ice in the winter time. They argued that we should find the surface covered deep

[1] See page 254.

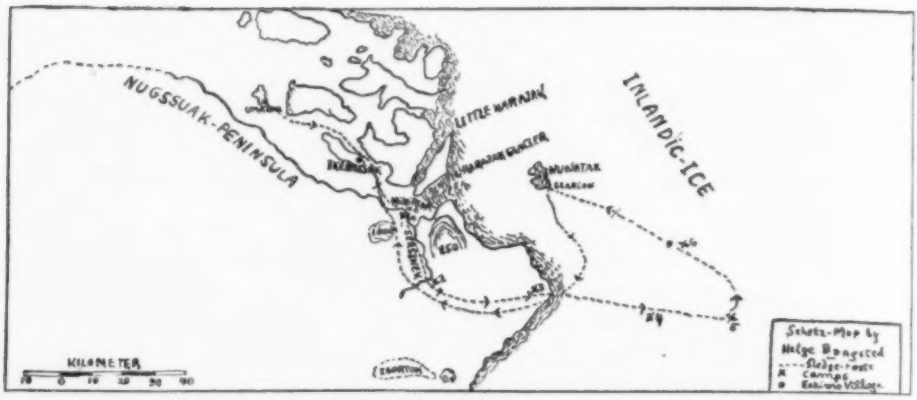


FIG. 1. MAP OF THE VICINITY OF UMANAK TO SHOW THE ROUTE FOLLOWED BY THE EXPEDITION

with soft snow; but this I could not believe, for all explorers of the inland-ice had reported there is always a wind blowing outward from the interior, and wind always compacts the snow and gives it a hard surface. It was therefore difficult to understand how the surface could consist of deep soft snow.

The next morning after reaching Isortok we started off on the inland-ice over the best sledging surface I had ever seen either in Greenland or in Arctic North America when I was connected with Rasmussen's Fifth Thule Expedition of 1921–1923. I had planned to go in to the big nunatak (rocky island within the ice) which lay to the northward and in a general direction to the eastward of Kekertak, but which had as yet never been visited. The Greenlanders had had much to say of the dangerous crevasses which they asserted lay between my present position and this nunatak; and so, instead of steering direct, I shaped my course to the south of east in order to keep clear of them. Not until we were about 80 kilometers in from the ice-margin did I change my course and steer directly for the nunatak itself.

By the middle of February I had reached the nunatak with no difficulties except such as are caused by the cold and stormy weather with drifting snow. Upon the inland-ice close to the nunatak I now set up a rather primitive meteorological station, and here I made observations every hour. This was possible because of the three members composing the party. Throughout eighteen days and nights of drifting stormy weather these observations were kept up (see page 255).

The Sersinek Ice

As has already been explained, we had encountered a very big area of *sersinek* ice along the course of the river which runs out to the Karajak fjord to the southward of the little island of Kekertak. The origin of such ice has a great deal of interest for the scientist, and in Greenland, where rivers usually disappear in the winter-time and are not common even in summer, the *sersinek* ice is very limited in its occurrence. It is restricted, apparently, to the areas of the basalt sheets, particularly Disko Island and the peninsulas of Nugsuak and Svartenhuk, but here it is of common occurrence.

In the autumn when air temperatures are low enough for freezing of the river, a cover of ice forms and by another month the mouth of the river will be frozen solid to the bottom. The water

coming from the springs within the basalt sheets now flows out over the ice-dam near the coast. The pressure of the water may break the ice-dam, but it floods a wide surface, and in calm weather a very thin ice cover will form over the flooded area, and large openings within this cover will permit the water to issue at the surface and again overflow. This process may continue throughout the entire winter.

Observations made on the Inland-ice

On two occasions during our stay of eighteen days near the nunatak[2] we had strong north-east storms, each of which blew for three days in succession. A vast amount of snow was carried out by the wind, and when we went outside the tent we found the drift so thick that we could hardly see the hand when held before the face. When we first reached the nunatak the ice surface had very little snow upon it, but when we left there was a snow cover about six inches deep and this was not soft but hard. The strong blizzard winds had packed the snow together. In the first of these blizzards our tent had been blown to pieces, and it was a very difficult matter to put it again in such a state as would protect us from the snow and the much worse wind.

During these northeast storms we had some days with foehn-wind. At such times the thermometer rose very quickly from—37° C. (–34° F.) to –8° C. (+ 18° F.). Long before the arrival of the foehn we could see the fine foehn clouds off to the southeast. The foehn-wind is a particularly trying wind to encounter on the inland-ice during the winter-time. Very quickly the snow becomes wet, and it collects on the clothing and, what is worse, on the sledge-runners as well.

Throughout our entire stay on the inland-ice I observed that the wind was always blowing outward from the interior of the inland-ice. We had not a single day—not a single hour—when the wind blew inward from the land toward the ice. Another fact is worthy of mention here. On some days we had no wind at all within the depressed areas of the ice-surface, though at the same time it was drifting very badly upon the higher surfaces. I especially noticed this when we were returning to Umanak. Whenever we were on the top of a ridge we encountered the strong northeast wind and drifting snow, but when we had rushed down into a depression of the surface the wind and drift ceased. Only with very strong wind have I observed the wind and drift within the valleys also.

The Surfaces of the Inland-ice

As already stated, the inland-ice comes down into the Nugsuak peninsula as a long tongue. On this tongue there was very little snow, not more than two or three inches, and this snow was not, as had been believed, soft but hard. It would be reasonable to suppose that because of the constant drifting outward there would be a large amount of snow, and perhaps also soft snow, at the edge or very close to the edge of the inland-ice. Also because of the heavy drifting near the nunatak it would be easy to believe that the snow would stop and be deposited near the edge of the inland-ice. But this is not so, and the reason is simple enough. The tongues which go out from the inland-ice have a very slight gradient and the surface of the ice is smooth. There is, therefore, nothing to stop the drifting snow until it has reached the big hills on the peninsula. The results are much the same wherever these conditions prevail near the west coast of Greenland, and little ice is deposited at the ice-margin during the winter. Farther south, however, where there is a good deal of hummocky ice, the rough surface will, of course, stop the snow and the valleys between the hummocks will become filled up.

[2] About twenty miles within the ice margin.

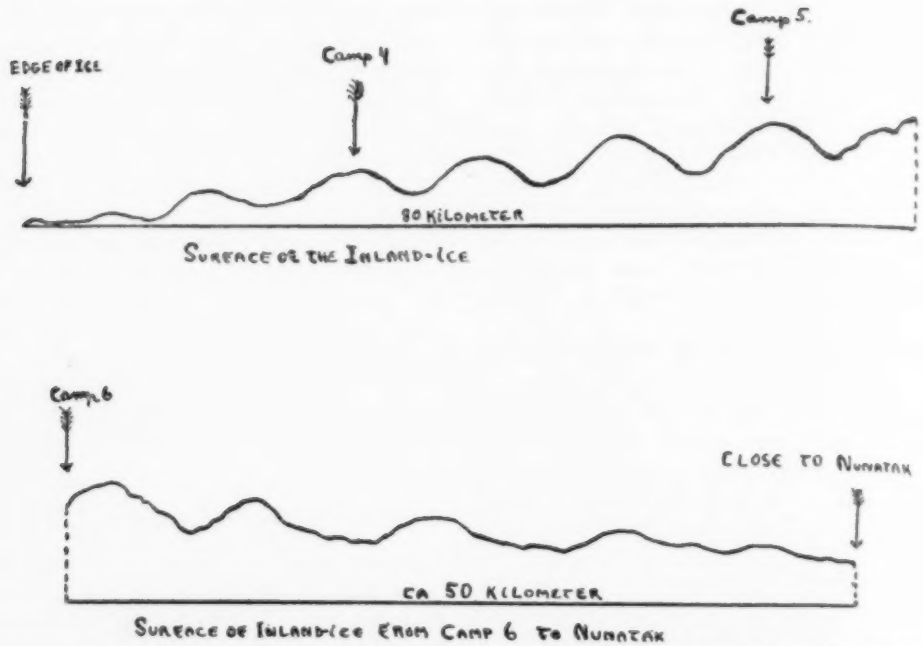


FIG. 2. PROFILE ALONG THE ROUTE OF THE EXPEDITION FROM THE EDGE OF THE INLAND-ICE TO THE STATION CLOSE TO THE NUNATAK

Inland-ice Sledging in Winter

The sledge trip here described was undertaken as a reconnaissance in preparation for expeditions which I have hoped to make later. Heretofore practically all travel over the inland-ice of Greenland has been restricted to the summer season. If a man can manage to live on the inland-ice in the winter, when there is no sunlight or only a few hours of sunlight each day, we are certain to learn much of great interest and value, and from the little trip which I have made I know that it is possible. The chief difficulty[3] is to protect oneself against the frost, and especially against the wet foehn-weather; and then, of course, one must be able to take in sufficient food for oneself and the dogs. On the journey here described we lived mainly on seal meat and on raw frozen halibut—very good as food but also very heavy. There is but one way to manage it if the expedition is to spend a long time on the ice. There must be a sufficient supply of pemmican, the one type of concentrated food which is adapted to ice conditions. Equally important is it to be provided with the very best fur clothing and sleeping-bags that can be obtained.

[3] As a member of the University of Michigan Greenland Expedition of 1927–1928, Mr. Bangsted is now (November, 1927) at the base of this expedition located at the head of the Söndre Strömfjord under the Arctic Circle in southwest Greenland, and with Professor J. E. Church, Jr., will attempt during the coming winter to penetrate by dog-sled the inland-ice for a distance of perhaps one hundred miles where within a cave in the snow they will attempt to set up for as many weeks as is practicable a meteorological station.—The Editor.

CAPTURE OF AN OCEAN SUNFISH

By Dr. E. W. GUDGER

AMERICAN MUSEUM OF NATURAL HISTORY

SOME years ago I published a short note[1] on a thirty-foot whale shark, *Rhincodon typus*, captured by being speared on the bow of the Munson liner *American Legion*. This occurred on May 19, 1923, in Lat. 17° 57′ S. and Long. 38° 41′ W., northeast of the Abrolhos Light, off the southeast coast of Brazil. Recently I have recorded[1] an absolutely similar capture of a fish of the same species and about the same size in the northwestern part of the Gulf of Guinea, near the mouth of the Sassandra River, in Lat. 4° 28′ N. and Long. 6° 24′ W.

The New York daily papers of October 18, 1926, all carried an item from the New York offices of the United States Steamship Lines concerning a somewhat similar capture of a large fish. This was contained in a wireless message from Capt. A. B. Randall, of *The Republic*, reporting a storm as follows: "Easterly gale three days. Only damage caused by an 800-pound live fish, unknown species, washed aboard by heavy seas over forward hatch, carrying away part of rail."

The rotogravure sections of the New York papers of Sunday, November 7, contained pictures of the fish, which at a glance was recognized as *Mola mola*, or, as it is often called, *Orthagoriscus mola*, the ocean sunfish.

A letter to the office of the United States Lines brought four excellent photographs from the Press Aid Department, showing the fish in position as it landed on the rail of *The Republic*. Two of these are herewith reproduced with appreciative thanks to the publicity department of the steamship company.

A letter to Captain Randall brought a courteous answer, giving the following details. The fish came aboard on October 17, 1926, when the ship's position was Lat. 49° 58′ N. and Long. 25° 05′ W. —near the center of the north Atlantic. The manner of its boarding the vessel was as follows:

> A moderately easterly gale had been blowing for three days, and the ship was pitching heavily and shipping solid water over the bows. At times the bow of the vessel would go under as much as seven feet, and it was at one of these moments that the fish came aboard.

The extreme ("over all") length of the fish was six feet, its thickness in a right and left direction was twenty-eight inches, its depth just forward of the huge dorsal and anal fins was forty-two inches, and its weight was estimated at 800 pounds. To get the total depth one must add the heights (about twenty inches each) of the two fins named (the dorsal and anal fins) —42 + 20 + 20 = 82 inches. The fish then was 6 feet 10 inches deep by 6 feet long. This specimen is to be judged as about two-thirds grown in comparison with fully adult specimens.

The American Museum possesses a mounted specimen measuring 10 feet in length by 11 feet vertical (over dorsal and anal fins). This was taken in 1910 off the coast of Southern California. The mounting of this fish proving unsatisfactory, it has been prepared by the Akeley method and now gives us a very handsome specimen of this interesting fish. At the time of its capture this

[1] Gudger, E. W. "An Extraordinary Capture of the Giant Shark, *Rhincodon typus*." *Natural History*, 1923, Vol. 23, pp. 62–63. "A Second Whale Shark, *Rhincodon typus*, Impaled on the Bow of a Steamship." *Bulletin*, New York Zoological Society, 1927, Vol. 30, pp. 76–77, fig.

A NEARER VIEW OF THE OCEAN SUNFISH

AS IT CAME TO REST ON THE RAIL OF THE STEAMSHIP "REPUBLIC." NOTE THE COLOR MARKINGS.

specimen was the record fish of its kind and was so described by Dr. Bashford Dean.[2] A photograph of the newly mounted fish is herein reproduced as figure 3.

Recently Mr. Zane Grey, the well-known novelist and deep sea angler, has presented a large mounted specimen of the sunfish to the new Hall of Fishes of the museum. This measures 7 feet 6 inches in extreme length and is 10 feet deep. The dorsal and anal fins are each 2 feet 9 inches long, and this leaves the depth of the body proper 4 feet 4 inches. The estimated thickness (right-left diameter) is 4 feet 6 inches. The diameter of the eye is 3 inches.

Other almost equally large specimens are on record. Dr. David Starr Jordan saw one which was taken in 1893 near Los Angeles, California. Its length is given as 8 feet 2 inches "over all," and its weight as 1,800 pounds. In 1915 Dr. B. W. Evermann[3] examined and measured in San Francisco a large specimen captured about 40 miles off the Golden Gate and south of the Farallones. This was 9 feet long and 7 feet 9 inches deep. The dorsal fin, which had been mutilated, was 2 feet 5 inches long and 23 inches wide, and the anal measured 21 inches in length. The eye was 5 inches in diameter. The fishermen estimated its weight at 2,500 pounds, but Evermann's estimate was 1,800 pounds.

Another very large specimen was captured off Santa Catalina Islands in 1919 by Van Campen Heilner. This he fig-

[2] Dean, Bashford. "A Record Sunfish." *American Museum Journal*, 1913, Vol. 13, pp. 370–371.

[3] Evermann, B. W. "Note on an Unusually Large Ocean Sunfish." *Copeia*, 1915, No. 20, pp. 17–18.

THE OCEAN SUNFISH

WHICH CAME ABOARD THE STEAMSHIP "REPUBLIC" IN MID-ATLANTIC. NOTE THE SIZE COMPARED WITH THAT OF THE MEN STANDING NEARBY.

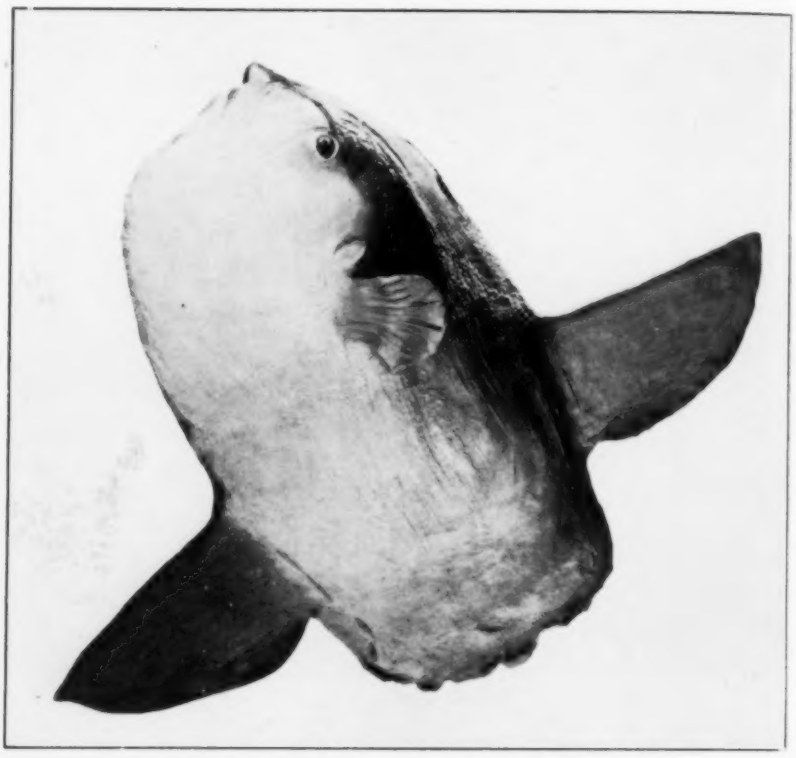
ured and described in 1920.[4] It measured 10 feet 11 inches from tip of snout to tip of tail fin, and 10 feet 9 inches in depth from tip to tip of dorsal and anal fins. This is the most symmetrical fish of which measurements are available.

However, the record sunfish (unfortunately not attested by any scientific man) is figured and described in *The Wide World Magazine* for December 10, 1910, pp. 204–205.[5] The capture of this great fish bears a not remote resemblance to that which forms the subject of this article, since it was taken also by a steamer—but by the propeller. Here follows the account:

When the *Fiona* [a twin screw steamer belonging to the Colonial Refining Company of Sydney, New South Wales] was off Bird Island, about forty miles north of Sydney Heads, on her way from the Clarence River to Sydney, a little after 1 p. m., all hands were alarmed by a sudden shock, as though the steamer had struck a solid substance or wreckage. The result was strange and remarkable, for the port engine was brought up "all standing." The starboard engine was quickly stopped and a boat lowered and sent to investigate. On getting under the steamer's counter the boat's crew were astonished to find that a huge sun-fish had become securely fixed in the bracket of the port propeller. One blade was completely embedded in the creature's flesh, jamming the monster firmly against the stern-post of the vessel. It was impossible to extricate the fish at sea, so the boat was hoisted on board again and the steamer proceeded on her passage to Sydney with the starboard engine only working. On reaching Port Jackson, the *Fiona* was anchored in Mosman Bay, where all hands were set to work to remove

[4] Heilner, Van Campen. "Notes on the taking of an Ocean Sunfish (*Mola mola*) off Santa Catalina Island, California, September 3, 1919." *Bulletin* New York Zoological Society, 1920, Vol. 23, pp. 126–127, fig.

[5] I am indebted to Dr. F. A. Lucas for calling my attention to this interesting note, and for the loan of a copy of the journal.

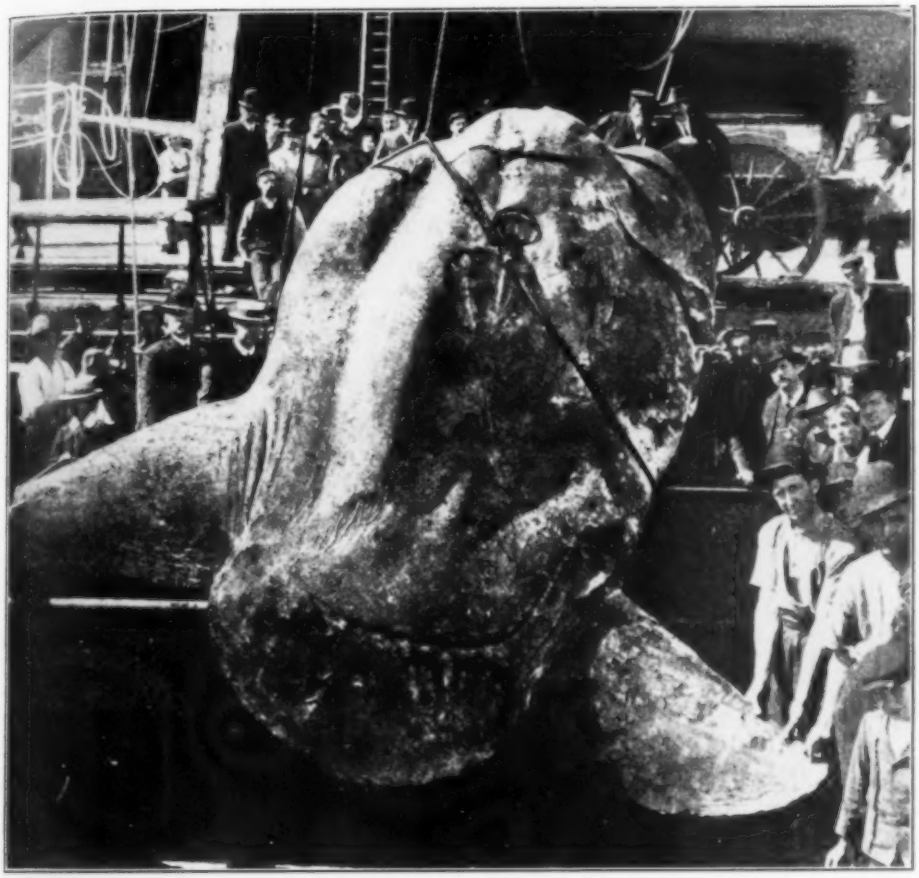


THE HUGE MOUNTED *ORTHAGORISCUS MOLA*
IN THE HALL OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY.

the fish. After much difficulty, and with the aid of the steamer's winch, the sun-fish was hoisted clear and swung on board. The *Fiona* then proceeded to the Sugar Company's wharf. The fish was put on the company's weigh-bridge, and found to weigh two tons four hundredweights. The measurements were: Length, ten feet; across the body, six feet; across the body and fins, fourteen feet; mouth, eight inches wide; dorsal fin, four feet high and two feet six inches across; anal fin, three feet six inches; and the caudal or tail fin, twenty-two and a half inches long—a short, fringe-like stump. The flesh near the mouth, where the propeller cut through, was a large mass of whitish cartilaginous substance.

The figure of this fish is herewith reproduced (no. 4 herein), and its size compared to the height of any of the bystanders does not seem to have been exaggerated in the above account. This figure shows three large cuts inflicted on the left side of the head of the fish by the blades of the vessel's propeller—one just in front of the left gill opening, another in the left side of the chin region, and behind these a huge cut in the lower jaw and throat region. Here it was that the propeller blade was imbedded in the thick cartilaginous-like material lying just underneath the skin, and the engine was "brought up all standing."

The capture of both these fish is undoubtedly due to the structure and habits of *Mola*. The short, stumpy, aborted caudal fin is of no service whatever as an agent of locomotion. The thick, heavy, stiff dorsal and anal fins are far from efficient helps in swimming. It does

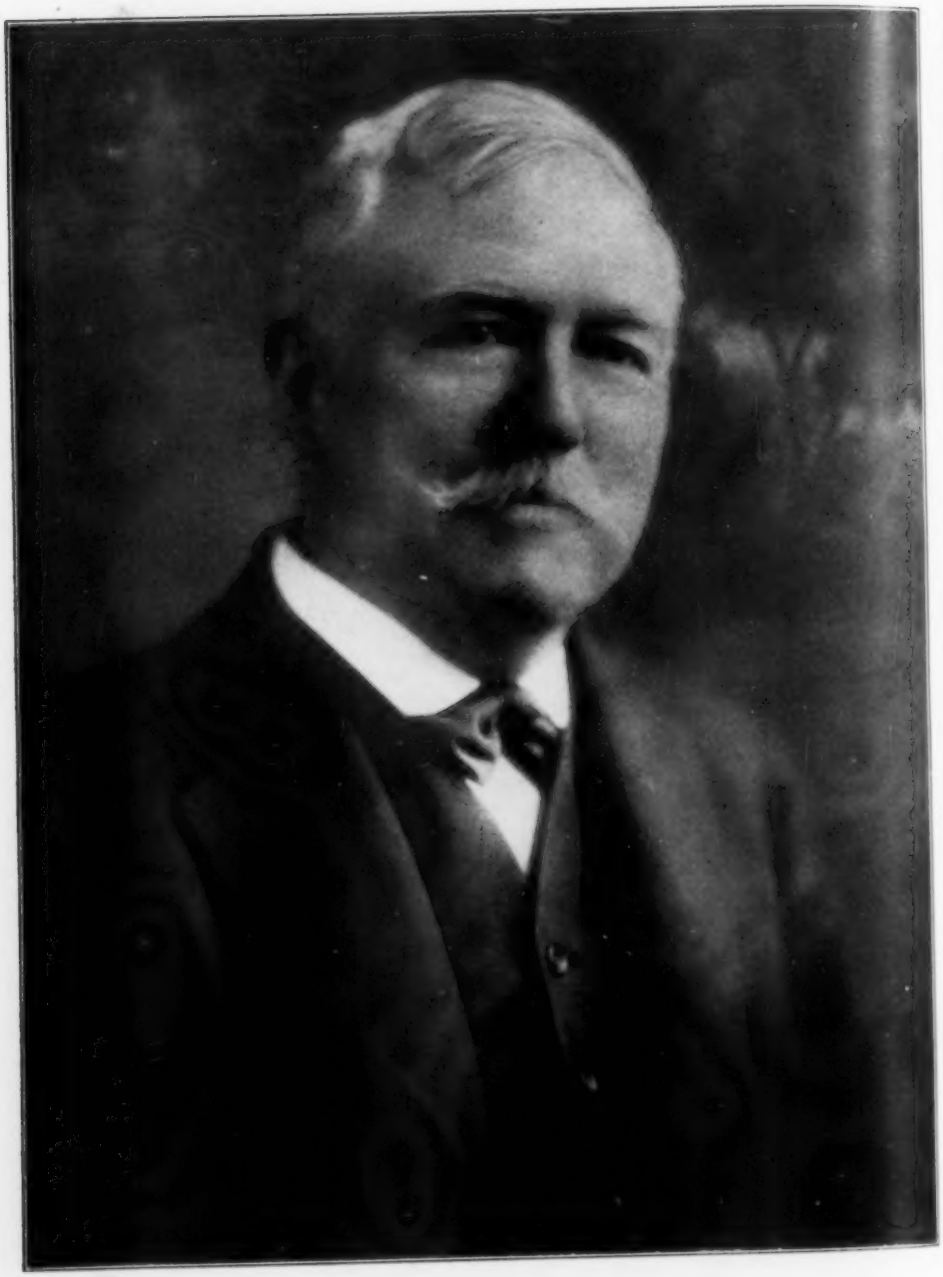


THE RECORD OCEAN SUNFISH

(LENGTH 10 FT., DEPTH 14 FT., WEIGHT 4,400 LBS.) CAUGHT IN THE PROPELLER OF A STEAMER NEAR SYDNEY, AUSTRALIA.

progress somewhat by slow flappings of these fins, the dorsal projecting above the water generally, but it is most often seen lying on one side at the surface of the water slowly carried along by the waves and currents.

While thus floating at the surface, Captain Randall's fish was picked up and washed aboard as the vessel drove her nose through the waves. In the same way the Australian specimen fouled the vessel's propeller by being drawn close alongside her as she passed the floating fish. Certainly, however, these are two of the most extraordinary captures ever recorded for such a large fish.



EDWARD EMERSON BARNARD[1]

By Professor ROBERT G. AITKEN
LICK OBSERVATORY

NASHVILLE is known as a prosperous commercial city, as the capital of a great state, and as one of the foremost educational centers in the Southern States. Founded as "the advance guard of western civilization" in the days of the war of the revolution, it has had a long and honorable history, with many achievements of which its citizens and all Americans may well be proud. But to the astronomers of my generation all of these claims to recognition are secondary to the fact that Nashville was the birthplace and early home of a man whom we greatly honored and deeply loved—Edward Emerson Barnard.

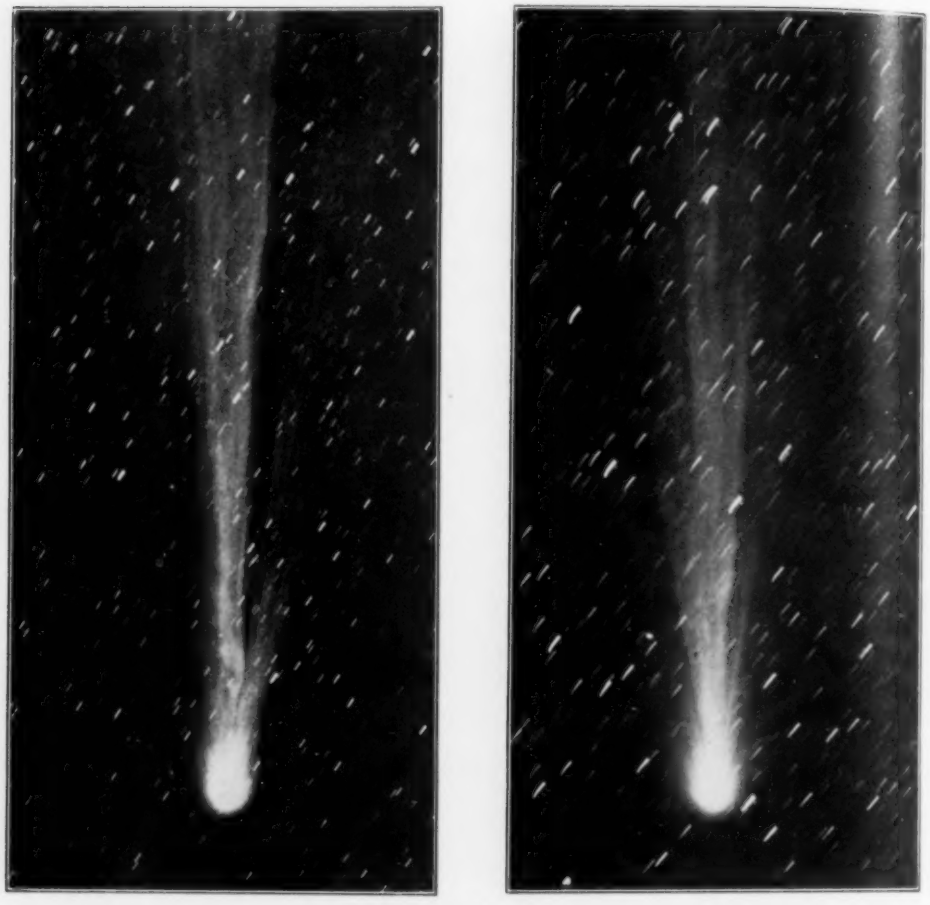
It is my privilege, as retiring chairman of Section D of the American Association for the Advancement of Science, to tell you something of his life and work, that you may know why we so honored and loved him, and to tell you also something of the progress of astronomy in America in those fields in which he was most interested and which his own work helped to make fruitful. It is peculiarly appropriate that special tribute be paid to Barnard's memory on this occasion, for not only was Nashville his birthplace, but it was at the first Nashville meeting, in 1877—fifty years ago—that he became a member of the association.

The story of Barnard's early life has been told many times, but it will not be amiss to repeat it, at least in outline, for, according to the behaviorist school of philosophy, what a man is and does in his mature years is conditioned almost exclusively upon the environment of his childhood years. It is not necessary to subscribe to this doctrine and all that it implies to recognize the fact that hard and bitter as were many of his experiences, the circumstances of his early life had a controlling influence in shaping the course of his later career.

Edward Emerson Barnard was born just seventy years ago this month—on December 16, 1857, to be precise. His father, Reuben Barnard, himself a poor man, had died before the boy's birth, and upon his widow, Elizabeth Jane (Haywood) Barnard, fell the heavy burden of providing for herself and her two young sons. The years of the Civil War, and those immediately following, were bitter ones, and a poor family must have suffered many hardships. Children, even very young children, had to help to earn their own support, and it is not surprising to learn that Edward Barnard attended school but two months in his boyhood, and that he went to work at an early age.

But that does not mean that his education was neglected. His mother was a woman of character and of ideals and to her the boy owed not only the rudiments of his education but also inspiration for his struggles throughout his boyhood and youth. Her health failed under the strain of work and care and for some years she had to give up the attempt to have a home of her own. It was only after Barnard's marriage that he had the great satisfaction of having his mother with him again, to be cared for by him, and particularly by his wife, until her death in 1884.

[1] Address of the retiring chairman of Section D, Astronomy, at the Nashville Meeting of the American Association for the Advancement of Science, December 28, 1927.

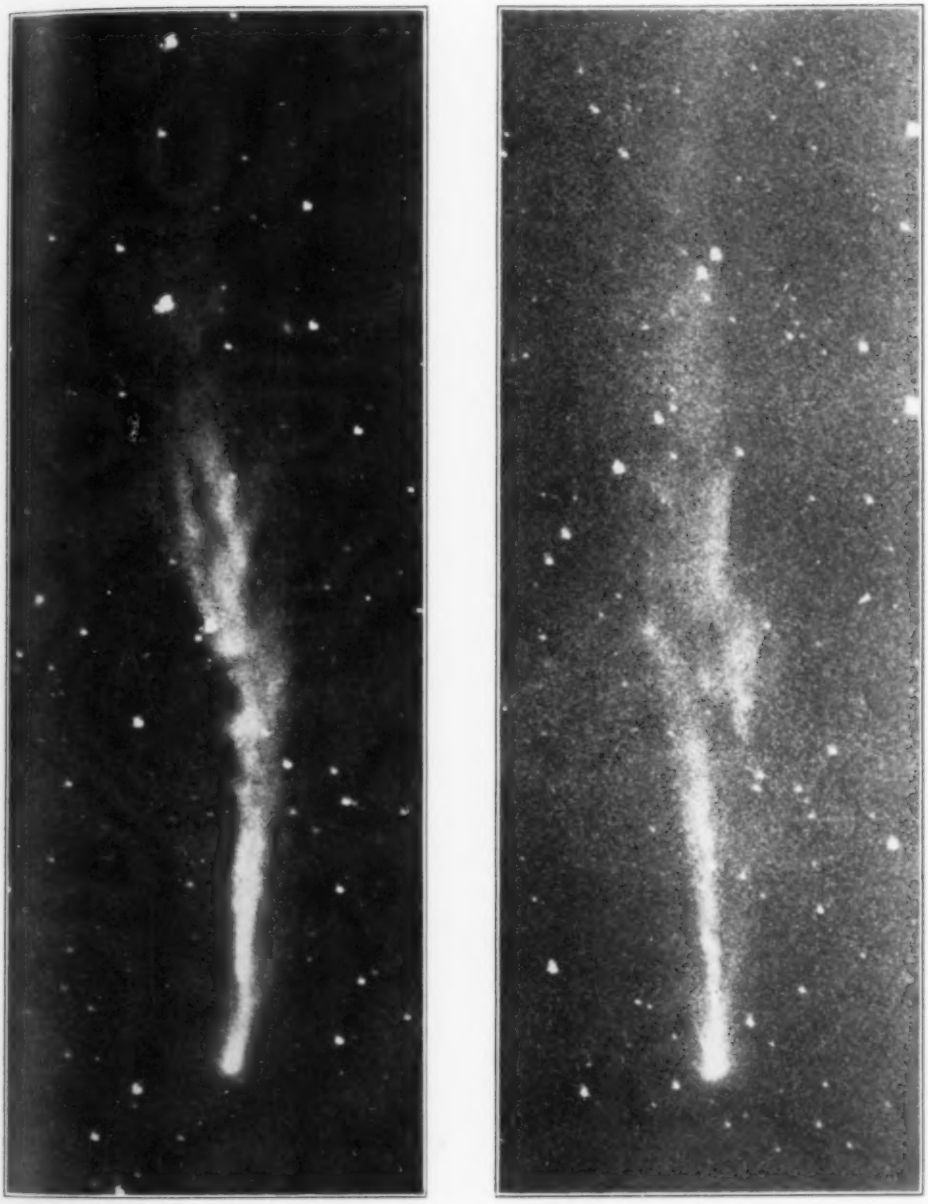


COMET SWIFT

PHOTOGRAPHS TAKEN BY E. E. BARNARD, WITH THE CROCKER TELESCOPE, AT THE LICK OBSERVATORY. THE LEFT-HAND PHOTOGRAPH WAS TAKEN ON APRIL 6, 1892, AND THE RIGHT-HAND PHOTOGRAPH ON APRIL 24, 1892

One circumstance of Barnard's early environment should be noted particularly. In those days the stars were still visible over the whole night sky to dwellers in all but the very largest cities; they were not hidden by sky-scrapers nor dimmed by the glare of arc-lights. So we find the boy, while still a small child, lying out in the open air in an old wagon bed, flat upon his back, on pleasant summer nights, watching the stars. He made friends with them and learned to trace and to recognize their apparent configurations long before he knew the name of a star or of a constellation, and long before he had any conception of the nature of a star. He welcomed them when they came round each year as he would welcome friends returned after a long absence. "Even to this day," he wrote in 1907, "this same friendship for the stars still holds . . . The coming of the Pleiades, of Orion or of the Scorpion I hail each year with the welcome of a friend."

When Barnard was but nine years old, he undertook a task in which many boys had failed. This was to keep a



COMET BROOKS

PHOTOGRAPHS TAKEN BY E. E. BARNARD, WITH THE CROCKER TELESCOPE, AT THE LICK OBSERVATORY. THE LEFT-HAND PHOTOGRAPH WAS TAKEN ON OCTOBER 21, 1893, THE RIGHT-HAND PHOTOGRAPH ON OCTOBER 22, 1893. NOTE THE EXTRAORDINARY CHANGE IN THE TAIL OF THE COMET IN THE 24 HOURS BETWEEN THE DATES OF THE TWO PHOTOGRAPHS

great enlarging camera on the roof of a photographer's studio constantly directed at the sun. Faithfulness and patience were the prime requisites for this work and these Barnard did not lack even as a boy. Indeed, he so fully justified the confidence placed in him that he continued to work in this studio —the Van Stavoren Gallery—for seventeen years, gradually becoming thoroughly familiar with every detail of the wet-plate photographic process.

Throughout these years, while working regularly in the daylight hours, earning part at first, and later the whole of the living for the family, his evening hours were given to study, under the guidance and inspiration of his mother, and to watching the stars. A sober, rather sad, life for a boy, one would say, but one which formed the best possible foundation for his later brilliant work.

It was inevitable, given such a character and such aspirations, that sooner or later the way would open to wider knowledge of the stars. What we, in our ignorance, are pleased to call chance brought it to pass that Mr. J. W. Braid, the operator in the Van Stavoren Gallery, who, I am happy to say, still lives in Nashville, should find on the street the small objective of a broken spy-glass, and should be moved to make a pasteboard tube for it, fit an eyepiece at the other end of the tube, and let Barnard have it for his first telescope. Somewhat later a stray volume of the works of Thomas Dick fell into Barnard's hands, and in this he found his first star map and from it learned the names assigned to the stars and constellations he already knew so well by his own observations. Another home-made telescope, with lenses (purchased this time) of 2¼ inches aperture, followed; and in 1876 he bought for $400 a 5-inch telescope, equatorially mounted, from John Byrne, of New York. What this purchase represented in self-denial on the part of the boy and of his mother can best be indicated by saying that the cost of the telescope equalled about two thirds of a whole year's earnings!

With a telescope powerful enough for really useful work, with a zeal for observation of the stars that had already given him a local reputation, and with the increasing knowledge gained by his reading and study, he was ready to join the American Association when it met at Nashville, in 1877, and to profit by the advice he sought from its president, Simon Newcomb, as to further studies.

The year 1877 thus brought him to a new stage in his career. He heeded Newcomb's assurance that training in mathematics was essential to his progress and in the half dozen years that followed, we find him redoubling his efforts, studying not only mathematics but other subjects and, for a time, even engaging a special tutor to assist him. The telescope, too, was kept busy, and with it he laid the foundation for that intimate knowledge of the aspect of the heavens in which he excelled all astronomers of his generation.

Then, in January, 1881, he married Miss Rhoda Calvert, who had come to Nashville from England with her brothers. They were artists who found work in connection with the studio where Barnard was employed. It was a happy and a fortunate marriage, and Mrs. Barnard helped him and encouraged him in his efforts to improve his education, and helped him also in the care of his invalid mother.

Four months later, on May 12, 1881, he found his first comet in the early morning sky. He saw it again on the following night but could not locate it thereafter, and, as he had not announced his discovery, it received no ranking in the formal records of astronomy. But it stimulated his interest, and he began to hunt for comets systematically.

It is possibly true, as some astron-

THE GREAT STAR CLOUD IN SCUTUM

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, JULY 30, 1905; EXPOSURE $5^h\ 30^m$. "THIS, THE GEM OF THE MILKY WAY, IS THE FINEST OF THE STAR CLOUDS," E. E. B. A NUMBER OF THE DARK MARKINGS ARE APPARENTLY PROJECTED AGAINST THE QUITE UNIFORM BACKGROUND OF FAINT STARS. NOTE PARTICULARLY THE ONE LEFT OF THE CENTER AND NEAR THE EDGE OF THE PICTURE. "IT LOOKS LIKE A SMALL, DARK COMET, WITH A TAIL CURVING TO THE NORTH." E. E. B.

omers have rather scornfully said, that any one can find a comet if he will but look long and carefully enough. But that is a large "if." I recall that in my first years at the Lick Observatory, C. D. Perrine was searching for comets systematically. Evening after evening he swept the western sky, and morning after morning the eastern heavens, in such manner that he covered the entire night sky at regular intervals. Many a night he would come in to the 12-inch dome where I was at work and borrow the telescope to examine more carefully a suspicious looking object, only to find that it was a small nebula or a tiny cluster of very faint stars. In the comet-seeker these objects can be distinguished from faint comets which lack tails only because they remain relatively fixed, whereas the comet moves among the stars. It was not until he had given many months to such careful scrutiny of the skies that Perrine was rewarded by his first discovery and we, who knew of his careful, intelligent work, knew too that he had fully earned the credit that came from this, and from his later discoveries.

So with Barnard in those earlier days. On September 17, 1881, he found another comet and this time he sent word of the discovery to Lewis Swift, and through him to astronomers generally. This comet was therefore carefully observed and is known, in the annals, as Comet 1881 VI. The discovery had important consequences quite other than its bearing upon his reputation as an observer. Mr. H. H. Warner, of Rochester, New York, had offered a prize of $200 for each unexpected comet discovered by an American observer. This prize came to Barnard for the discovery of Comet 1881 VI. Mrs. Barnard felt that the money must be used for some definite purpose, and with her encouragement, and faith that later payments would be met "somehow," and that they would "manage," it was accordingly used as the first payment for a house. Faith, backed by hard work, had its due reward, for Mr. Warner's offer was continued for several years, and Barnard actually won enough prizes for cometary discoveries to pay for the "Comet House," as it is still known here in Nashville and to all astronomers.

By the year 1883 Barnard had made such progress in his studies that he was prepared to profit by the opportunity his reputation brought him. Friends who believed in him offered him a fellowship in Vanderbilt University. The stipend was but $300 a year and a house on the campus, near the observatory, but it was sufficient, thanks to Mrs. Barnard's courage and good management, to permit him to give up his studio work and to devote his entire time to his studies and to work at the observatory, which, with its 6-inch equatorial telescope, was put in his care. His name, therefore, appears on the rolls of the university as student, and also, in 1884–85 as assistant, in 1886–87, an instructor in practical astronomy.

In 1887, Barnard had completed a four-year course in the school of mathematics at the university, and though he did not at this time receive a degree, his record of cometary discoveries, his observations of Jupiter, his independent discovery, in 1883, of the Gegenschein—that feebly luminous patch of light that moves across the sky along the ecliptic, keeping always 180° from the sun—had given him such a reputation as a keen and reliable observer that Director E. S. Holden offered him a position on the staff he was organizing for the Lick Observatory, then nearing completion.

Forty years ago, therefore, at the age of thirty, Barnard had completed his apprenticeship and was ready to enter upon his career as a professional astronomer. As equipment for that career he brought an alert mind and a marvel-

REGION OF THE NORTH AMERICA NEBULA

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, 1905, SEPTEMBER 4; EXPOSURE TIME $4^h\ 20^m$. THIS WONDERFUL OBJECT "IS A SPLENDID MIXTURE OF STARS AND NEBULOSITY. ACCORDING TO WOLF, THE NEBULA IS GASEOUS. AROUND THE NEBULA ARE SCATTERED MASSES OF NEBULOSITY, LIKE ISLANDS OFF THE MAINLAND." E. E. B.

lously keen eye—a combination which produces what I like to call the "seeing" eye—a body inured to hardships, a thorough mastery of photographic processes, a sound knowledge of what had been done in astronomy, an intimate knowledge of the visible heavens, and, what was most important of all, an enthusiasm for observing that amounted to a passion. Speaking of this characteristic, Professor Frost writes, "To him, a night at the great telescope was almost a rite—a sacred opportunity for a search for truth in celestial places." And what was true of his work with the 40-inch Yerkes telescope was equally true of all his observational work.

The outward aspects of his later career need not long detain us, for, in the main, his life was the life of all astronomical observers; nights devoted to work in the domes, days given to development and examination of photographs, and to computations and the preparation of papers; with now and again a relatively short absence on an eclipse expedition or a trip to England; enforced interruptions to observing, while waiting, in 1887–88, for the completion of the Lick Observatory, in 1895–96 for the completion of the Yerkes Observatory; and one trying year, in 1914, when, under the doctor's orders, he had to give up work. It is worth while emphasizing, however, that rarely if ever, has an astronomer given such passionate devotion to his observational work as Barnard gave; a devotion that endured to the date of his last observation with the 40-inch on the night of December 21, 1922, less than two months before his death. Not cold, nor bodily fatigue, nor need for sleep could keep him from the telescope while the stars were shining.

It is the record he made as an observer that now concerns us—and what an extraordinary record it is![2] Most of us specialize; we study the planets, or the sun, or variable stars, or double stars, or the nebulae. Barnard's specialty, as I have said elsewhere, may be said to have been the visual or photographic observation of every description of object known in the heavens!

At the Lick Observatory, he was at first assigned to work with the 12-inch refractor, the comet seeker and the small photographic telescopes. Naturally, he kept up his search for comets, and the tradition at the observatory is that there was not an instrument on the place (except the meridian circle) with which Barnard had not found a comet—either an unexpected object, or one whose return had been predicted. One of these discoveries was that of Comet 1892 V, on October 12, 1892, the first comet found by photography. In a sense it was an accidental discovery, for the plate had been exposed, not to hunt for comets, but to photograph the region of the Milky Way near Altair. The discovery, however, bears testimony to Barnard's care in developing and examining his plates promptly, and to his alertness in at once recognizing the nature of the object.

Another discovery worth noting here is that of a small, round, nebulous looking comet on September 2, 1888. Such an object, as I have said, can be distinguished from a nebula only by its motion among the stars. Barnard could not detect motion in this object during the time he held it under observation that night, but, as he wrote later, *from his thorough knowledge of that region of the sky*, he had no hesitation in announcing it as a comet!

Far more interesting and important

[2] In the address, as delivered at Nashville, forty lantern slides were projected upon the screen, to illustrate Professor Barnard's work. The plates accompanying this article are from his negatives. I acknowledge, gratefully, the kindness of Director Frost, of the Yerkes Observatory, in permitting me to reproduce the photograph of the Milky Way. R. G. A.

REGION OF THE CLUSTER MESSIER 37 IN AURIGA

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, 1905, MARCH 31. EXPOSURE 1h 30m. EVERY WHITE DOT IN THE PHOTOGRAPH, OF COURSE, REPRESENTS A STAR. NO LUMINOUS NEBULAE ARE VISIBLE ON THE PLATE, AND PROFESSOR BARNARD WAS IN DOUBT AS TO THE NATURE OF "THE CURIOUS BLACK SPOT" ABOUT THE SIZE OF THE CENTRAL BRIGHT CLUSTER AND TO THE RIGHT OF IT

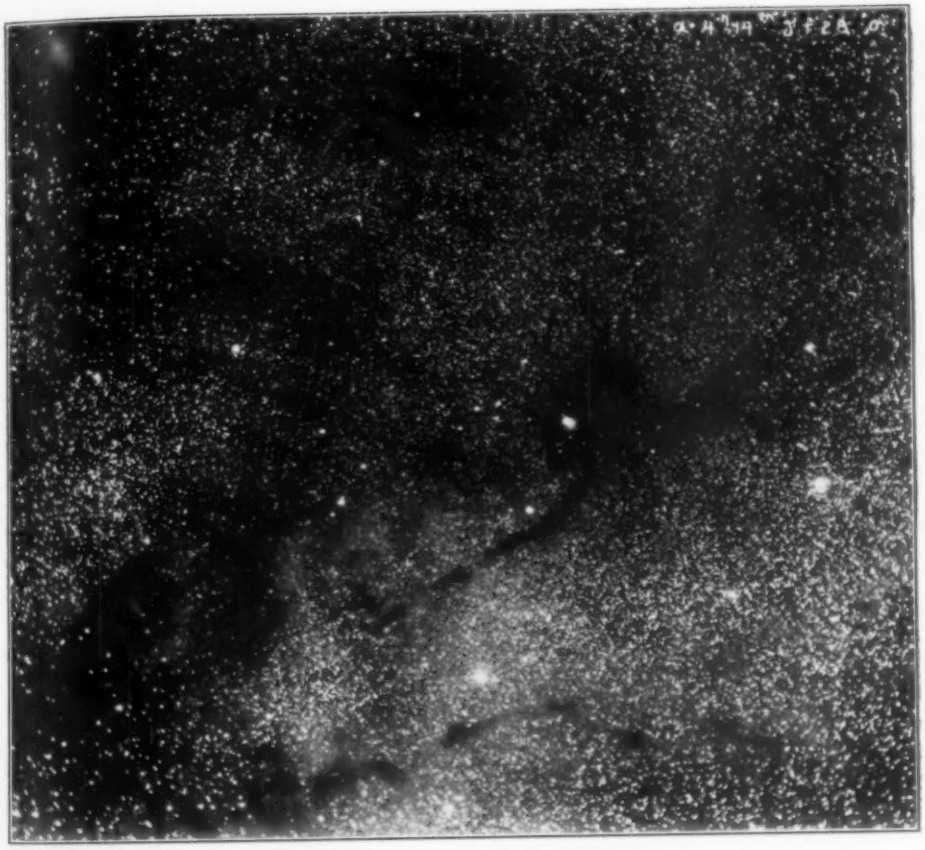
however, were the photographic studies of comets, and of the rapid changes that take place in the form and structure of the tails of comets, which Barnard initiated with the Crocker telescope of the Lick Observatory and continued later at the Yerkes Observatory, as opportunity offered. In this field, as in the field of Milky Way photography, Barnard was a pioneer, and the many hundreds of photographs of comets which he secured (more than 1,400 at Yerkes alone) still offer a rich material for detailed studies. His photographs of Swift's Comet of 1892, and especially of Brooks' Comet of 1893, revealed for the first time the remarkable motions and changes in the tail of a comet produced by the stimulating and repulsive forces directed upon it by the Sun when the comet is near its perihelion point.

The Milky Way had always fascinated Barnard, and he undertook a systematic photographic exploration of it with the Crocker telescope at Mount Hamilton as soon as that instrument was ready. These photographs revealed for the first time the marvellous richness of the star clouds of the Milky Way and their complicated structure. Later, with the more powerful portrait-lens doublet telescopes provided at the Yerkes Observatory through the generosity of Miss Catherine Wolfe Bruce, he continued these studies to better advantage. He also transported the Bruce telescope to Mount Wilson, in 1905, to photograph from that favored location the more southerly portions of the Milky Way that could not be seen well, if at all, from Williams Bay.

His earlier work at Mount Hamilton on the Milky Way and on comets has been published as Volume XI of the Publications of the Lick Observatory, and at this very time the Yerkes Observatory is distributing the "Photographic Atlas of Selected Regions of the Milky Way," whose publication has been made possible by a grant from the Carnegie Institution and by the skill and devotion of Mrs. Barnard's niece, Miss Mary Calvert, and of Director Frost. Professor Barnard himself passed upon every plate included in the earlier volume, and not only made the printing negatives for the fifty-one photographs included in the later work, but personally inspected and selected every one of the 35,700 prints for the edition of 700 copies.

This is not the occasion for a critical review of either of these books, and, indeed, it is necessary to examine the plates and prints themselves one by one, with the aid of the notes added by Barnard himself and by his editors, to appreciate fully the beauty of these photographs and their significance. Here it will be sufficient to direct attention to one or two features.

Every photograph shows such a crowded field of faint stars that it gives the effect of star clouds; but the distribution of the stars is not uniform and in many places there are great areas of true nebulosity. There are also innumerable dark lanes and what appear to be "holes" in these clouds, and these dark markings in particular attracted Barnard's attention. It is clear that at first he took them at their surface value and regarded them as vacant spaces. As time went on and he considered the question more carefully, studying minutely the details revealed on the ever-growing number of his photographs, his views gradually changed and he became convinced that here we have to deal, not with vacant regions, but with vast accumulations of matter that absorbs or occludes light, an interpretation which was offered by A. C. Ranyard as early as 1894. This is, of course, the view that is held by astronomers generally at the present time, and that it is correct will be fairly obvious to any one who studies carefully



NEBULOUS REGION IN TAURUS

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, YERKES OBSERVATORY, 1907, JANUARY 9. EXPOSURE 5^h 29^m. PROFESSOR BARNARD WRITES: "VERY FEW REGIONS OF THE SKY ARE AS REMARKABLE AS THIS ONE. THE PHOTOGRAPH . . . BEARS THE STRONGEST PROOF OF THE EXISTENCE OF OBSCURING MATTER IN SPACE"

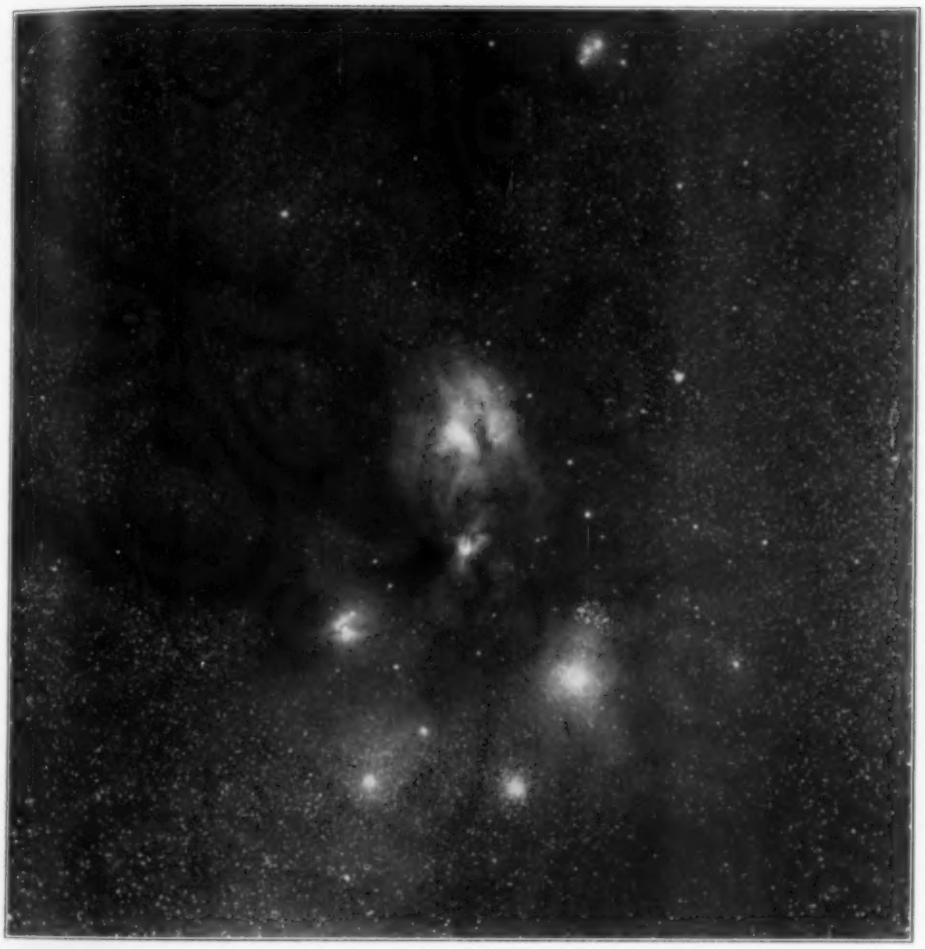
the large scale photographs taken with the powerful reflectors now available—and, in particular, those taken in recent years with the 60-inch and 100-inch reflectors on Mount Wilson. In many instances one is driven to the conclusion that light from the more distant objects in or near the galactic plane is obstructed by dark nebulous matter; in many others it is clear that the structure of the nebula is the same whether it shines or is revealed merely by contrast with its luminous background. To borrow Bessel's remark about the stars, the power to emit light, we believe, is not a necessary attribute of a gaseous nebula; indeed, this power, it is probable, does not originate in the nebula at all, but in the white hot stars enmeshed within it. Where these are lacking, the nebula does not shine.

Barnard himself called attention to the similarity in structure between luminous and dark nebulae, and his work did much to extend our knowledge of objects of the latter category, especially in the Milky Way. In fact his catalogue of these objects is, I think, the most extensive one we have.

I have dwelt first upon Barnard's work in comet discovery and in the photography of comets and of the Milky Way, because these lines of activity are most closely associated with his apprentice work in his early days at Nashville. But I believe, with Professor Frost that, devoted as Barnard was to work of this kind, and successful as he became in it, his great love was for visual observation with the powerful refractors that he had the privilege of using. He was first and foremost a keen-eyed observer. This was foreshadowed by his cometary discoveries at Nashville and his independent discovery of the Gegenschein, but was dramatically revealed to the astronomical world by his discovery of the fifth satellite of Jupiter with the 36-inch Lick refractor on September 9, 1892.

Jupiter had engaged his attention from a very early date, and one of his first contributions to the "Publications of the Astronomical Society of the Pacific" was a paper on his visual observations of the planet with the small telescopes he used at Nashville—and with the 12-inch telescope at Mount Hamilton. At first, naturally, as junior member of the staff, he had no opportunity to use the larger telescope. When this opportunity did come, he promptly utilized it to study Jupiter, then well placed for observation. He studied the planet's surface with keen attention, and also the sky in its immediate vicinity, with the definite purpose of ascertaining whether any satellites besides the famous four first seen by Galileo existed. When, on Friday night, September 9, 1892, he saw a tiny point of light close to Jupiter—so faint that the planet itself had to be thrown out of the field of view to permit it to be seen—he suspected its true character at once, but aside from communicating his suspicions in a letter to his good friend, Professor S. W. Burnham, then at Chicago, he said nothing about it until he was able to see the object again on the following night and to measure its motion outward to elongation and back toward the planet. His long series of measures in the following months and years established the period of the satellite with high accuracy, and the other orbital elements as well, and brought out the extraordinarily rapid motion of the line of apsides of the orbit produced by the perturbations to which the tiny body was subject.

This was but one, though, no doubt, the most brilliant of the results of his visual observations and measures of the planets and satellites of our system. Another striking observation, for example, was that of the eclipse of Japetus, the eighth satellite of Saturn, by the ring system of the planet in November, 1889. He saw the satellite through the so-called crepe ring, thus establishing



REGION OF THE GREAT NEBULA OF RHO OPHIUCHI

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, 1905, APRIL 5. EXPOSURE TIME, $4^h\ 30^m$. "THE REGION OF RHO OPHIUCHI IS ONE OF THE MOST EXTRAORDINARY IN THE SKY. THE NEBULA ITSELF IS A BEAUTIFUL OBJECT. WITH ITS OUTLYING CONNECTIONS AND THE DARK SPOT IN WHICH IT IS PLACED, AND THE VACANT LANES RUNNING TO EAST (LEFT) FROM IT, IT MAKES A PICTURE ALMOST UNEQUALLED IN INTEREST IN THE ENTIRE HEAVENS." E. E. B.

the fact that this ring is really transparent, and supporting Clerk Maxwell's famous conclusion that the rings consist of a swarm of innumerable tiny particles.

During the later years of his residence on Mount Hamilton, he carried out with the 36-inch telescope a long series of micrometrical measures of the diameters of planets and of satellites and of a few of the larger minor planets. The great accuracy and completeness of these measures gave them high value and to this day they set a standards for work of this character.

His long series of accurate measures of comet positions also demand mention. He was accustomed to follow any comet that he observed just as long as he could possibly see it with the 36-inch or 40-inch refractor, and his measures, in many instances, continued long after every other observer had abandoned the object as too faint to measure.

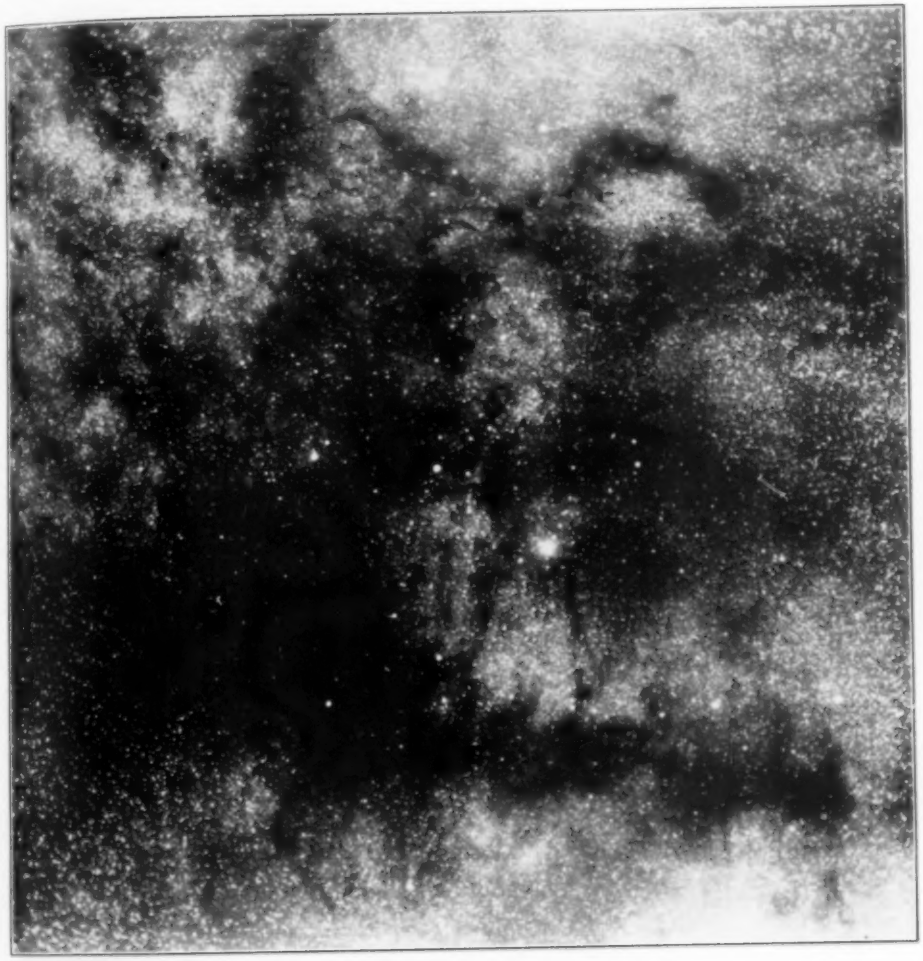
His visual observations, moreover, were by no means confined to bodies in the solar system. Double stars, variable stars, novae, star clusters and the nebulae all claimed his attention. Certain double stars he followed more systematically than did any other observer, and in the years covered by his observations it would suffice to depend upon his measures alone, discarding all others. I may cite Krueger 60, as a striking example, for I computed the orbit of this interesting binary system only a few years ago. I utilized all available measures, of course, but Barnard's measures from 1900 to 1921 were so numerous and so consistent that they practically determined the observational curve for this period.

Barnard's skill as a visual observer was also demonstrated by his determination of the parallax of Krueger 60, for his value, derived from micrometer measures, agrees with the best modern photographic results well within their probable error.

It would unduly prolong my address were I to refer to all of Barnard's interesting observations and discoveries, but I must include at least two others, the first being his measures of the expanding nebulous ring, or shell surrounding Nova Aquilae, No. 3, the remarkably brilliant new star which suddenly appeared on the night of June 18, 1918, and which was independently discovered by many watchful observers, Barnard himself being one of them. His measures of the nebulous envelope indicated that it was expanding, a fact which was fully confirmed by measures at Mount Hamilton with the 36-inch refractor, and by spectrographic observations. This has been shown by Hubble's photographic investigations in the present year still to continue, at a practically uniform angular rate, though the nebulous disk is now too faint to be measured visually.

The other discovery that must be referred to is that of the famous "run-away" star that will always be known as "Barnard's Star," for aside from its intrinsic interest, it gives a hint of the discoveries that may still be made in the course of the thorough examination of his great store of negatives that is now in progress at the Yerkes Observatory. Incidentally, too, it illustrates one of the great satisfactions that we find in careful astronomical observations, whether visual or photographic. The measures, or the photographs, may be made with one particular object in view; years, or decades, or centuries later they may be utilized to further our knowledge in ways of which the observer had not dreamed.

Barnard himself was so absorbed in the work of actual observation, either at the eye end of the great 36-inch and 40-inch refractors, or with the Crocker and Bruce photographic telescopes, that he was not able to give his photographic plates any exhaustive study. Indeed he did comparatively little in the way of measurement of photographic plates.



DARK MARKINGS NEAR THETA OPHIUCHI

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, 1905, JUNE 5. EXPOSURE 4^h 45^m. NOTE THE DARK S-SHAPED MARKING NEAR THE CENTER AND THE STRANGE CURLED FIGURE A LITTLE ABOVE IT. ALSO THE GREAT DARK LAKE TO THE LEFT AND BELOW THE CENTER, WITH THE DARK LANE RUNNING FROM IT TO THE RIGHT. CONTRAST THESE WITH THE STAR CLOUDS IN OTHER PARTS OF THE PICTURE

and it is doubtless true, as Professor Frost says, that he regarded his plates more as pictures of the heavens than as material for detailed measures. Occasionally, however, he did compare two plates of the same region, taken at different times, under the comparator, and such a comparison of a plate taken in August, 1897, with the Willard lens at Mount Hamilton, with one taken with the Bruce telescope at Williams Bay in May, 1916, revealed a faint star in Ophiuchus, having an annual proper motion of 10″.3, the largest known, even to-day. Such remarkable motion—rapid enough to produce in a single month a displacement measurable with our great modern telescopes—led at once to the inference that this star is one of our nearest neighbors, and investigations proved, as a fact, that its parallax is 0″.538, making the star second only to the system of Alpha Centauri in point of proximity to the sun. It is therefore intrinsically faint, though not nearly so faint as the third nearest star, Wolf 359, which van Maanen's recent measures have proved to be by far the faintest of all known stars.

This rapid survey of Barnard's observational work is necessarily impressionistic and incomplete, but it is sufficient to indicate the extraordinary range of his interests and his amazing industry, as well as his ability to plan his researches wisely and his alertness of mind in detecting the significance of any phenomenon he observed, whether it were a point of light near Jupiter, a faint and hazy trail on a photographic plate, or a halo about a bright star.

It must be kept in mind that Barnard served his astronomical apprenticeship in the days when the new astronomy, as it has often been called, was in the very infancy. Even in 1887, when he went to the Lick Observatory, this statement would hold. The parallaxes of very few stars had been measured; a little, but only very little, was known about the spectra of the stars; a few attempts, not very successful, had been made to measure, visually, the radial velocities of stars; a beginning, but merely a beginning, had been made in astronomical photography, and practically nothing was known of the stars as organisms.

Barnard's training did not fit him to engage successfully in spectroscopic observation and research, but it did enable him to become one of the great pioneers in astronomical photography. His photographs of comets have never been excelled; his photographs of the Milky Way structure are surpassed, in detail, only by the large scale plates taken with the great modern reflectors; his photographs of planets—of Mars in particular—were equal to the best that had been made up to the time of his death.

It was but natural, however, that he should find his greatest satisfaction in direct visual observations and measures with the powerful refractors he had at his command, for he was first and foremost an observer. He had the seeing eye. This is shown by his astronomical work, but was also evident from his delight in the observation of animals, birds and trees. In other circumstances he would have won renown as a naturalist.

Membership in the National Academy of Sciences, and in many other societies of the highest standing at home and abroad, honorary degrees from colleges and universities; medal awards by academies and societies in France, in England and in America, all attest the widespread regard and respect for the man and for his work. Barnard, the greatest astronomical observer of his generation, was honored throughout the scientific world; Barnard, the modest, simple-minded, unselfish, kindly man, was loved by every one who knew him.

THE PROGRESS OF SCIENCE

THE SCIENTIFIC WORK OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

THE distinguished line of succession in the secretaryship of the Smithsonian Institution—Joseph Henry, Spencer F. Baird, S. P. Langley and Charles D. Walcott—has been continued by the election of Dr. Charles Greeley Abbot, who has been acting secretary since the death of Dr. Walcott a year ago and has been identified with the work of the institution for thirty-three years.

Dr. Abbot was born on a New Hampshire farm, in 1872, and graduated from the Massachusetts Institute of Technology, where he worked especially with Professor A. A. Noyes. In 1895 he went to the Smithsonian as assistant to Professor S. P. Langley in the Astrophysical Observatory. Langley was at that time trying to plot the Fraunhofer lines in the invisible infra-red spectrum, with the aid of his bolometer, but instruments were not yet delicate enough. Dr. Abbot improved the setting of the bolometer and the bolometer itself. He eliminated very largely the effect of earth jarring and trembling and temperature effects. The resultant plotting of the infra-red spectrum is the classic work on the subject.

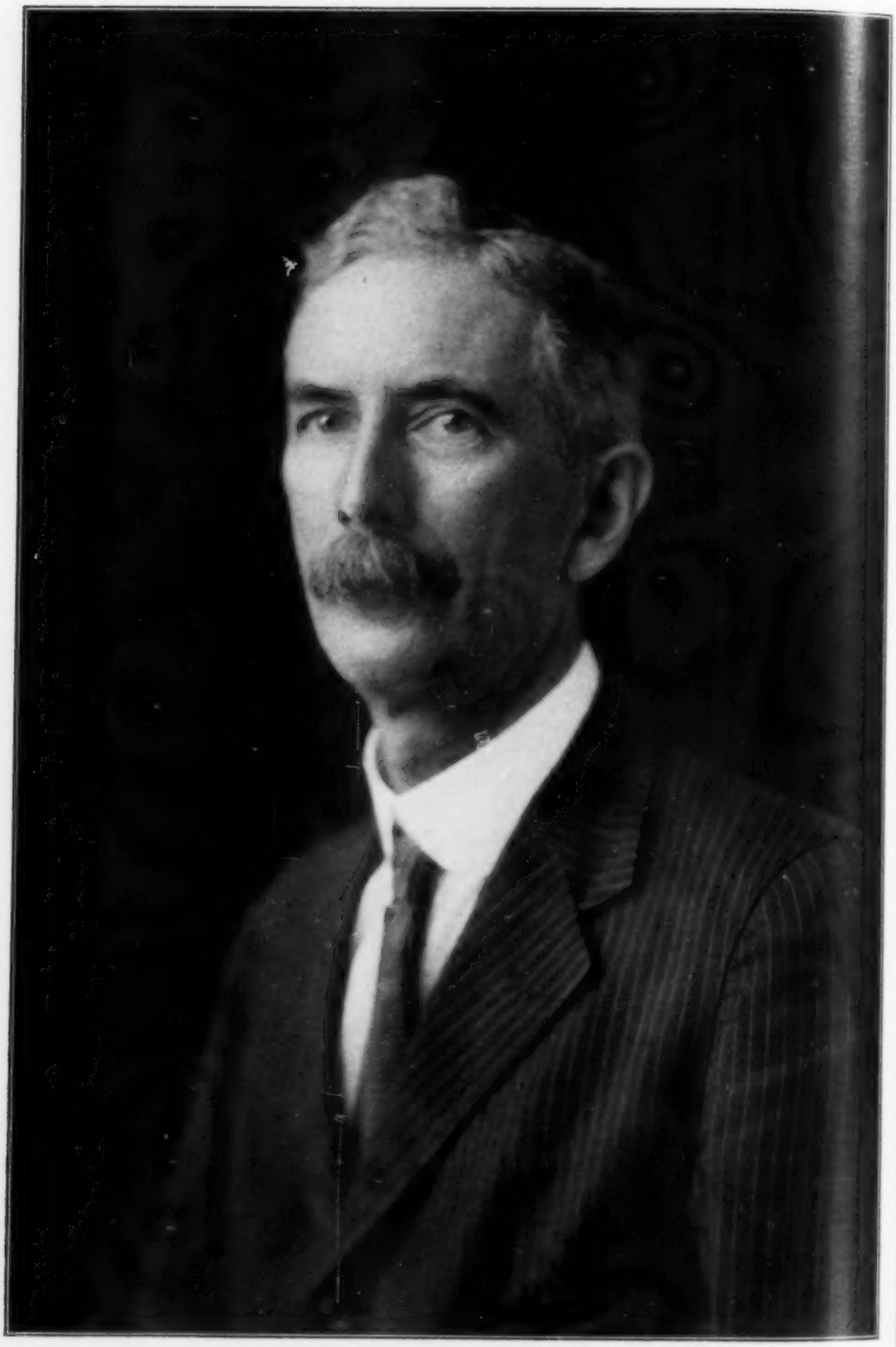
In 1902 Professor Langley and Dr. Abbot began their work on the intensity of the radiation of the sun. Until 1907 Dr. Abbot made solar constant measurements at the Smithsonian Institution in Washington. With the establishment of the Carnegie Observatory on Mt. Wilson in 1905, its director, Professor George E. Hale, invited the Smithsonian to send observers to measure the solar constant there.

In 1907 and 1910, while colleagues observed on Mt. Wilson, Dr. Abbot made complete solar constant observations on the extreme summit of Mt. Whitney at 14,500 feet. Almost perfect accord was found between the results at Mt. Wilson and Mt. Whitney, showing, when considered with Washington observations, that from sea level to an elevation of nearly three miles, the Langley method, as perfected and practiced by Dr. Abbot, gave results independent of the altitude of the observer.

Dr. Abbot now undertook still another test. Apparently the sun varied. Were the variations really solar, or were they brought about by obscure atmospheric sources of error not yet eliminated. To test this question, he went to Algeria. There in 1911 and 1912, while his colleagues measured at Mt. Wilson, Dr. Abbot took observations. The results of the two stations accorded so well as to strengthen the conclusion that the observed variation was not being caused by local atmospheric conditions.

In 1913 and 1914 another experiment was made to prove that the means used to eliminate atmospheric influences were sound. Special recording pyrheliometers were constructed for measuring the intensity of the radiation of the sun at the highest altitudes which could be reached by sounding balloons. In 1913 five such instruments were sent up from Catalina Island, California. All were recovered and all had readable records made at about 14,000 meters. The instruments were improved and in July, 1914, three were sent up from Omaha, Nebraska, to 15 miles above the earth, one of which was recovered with record intact and results which again supported the correctness of Smithsonian measurements.

By 1926 proof of variation was reached. The essence of this final proof lies in a



DR. CHARLES GREELEY ABBOT

ELECTED SECRETARY OF THE SMITHSONIAN INSTITUTION

comparison of measurements of solar radiation received at the earth's surface made by the pyrheliometer for groups of days when the atmosphere is practically identical. The resulting curves followed exactly the original curves made by the solar constant measurements for the same days.

In 1918, Dr. Abbot, by advice of Dr. Walter Knoche, selected a site for a permanent station near Calama, Chile, and installed instruments made at the institution, under the care of trained observers for the work. Funds were furnished to remove this station to Mt. Montezuma in the year 1920, by Mr. John A. Roebling, of New Jersey. In 1920 a second station was established at Mt. Harqua Hala, Arizona, by Mr. Roebling's generosity, and with further aid from him this was transferred to Table Mountain, California, in 1925. In 1926, with funds from the National Geographic Society, Dr. Abbot established a third station on Mt. Brukkaros, South West Africa. These three stations in different hemispheres are producing measurements which can be checked against one another to get results of very great accuracy.

RESEARCH IN PHYSICS IN YALE UNIVERSITY

YALE UNIVERSITY has made public a report on the research work being conducted in the Sloane Physics Laboratory, which gives an interesting survey of the work of a single institution in a single science.

Professor Louis W. McKeehan, director of the Sloane Physics Laboratory, is continuing during his first year at Yale his work on the "shape" of metal atoms, on which THE SCIENTIFIC MONTHLY has had the privilege of printing an article by him. The particular effect Professor McKeehan is now studying is the change in electrical conductivity due to elastic pull in fine wires. Graduate students under his direction are working on related problems. Another possible source of information about atoms in solids is found in studying their arrangement by x-ray methods. Dr. L. M. Kirkpatrick, who holds a Sterling fellowship, and several graduate students are working on researches in which x-rays and crystals are of principal importance.

Professor Alois F. Kovarik is continuing his study of the condensation of radio-active gases (radon and thoron) on cold surfaces, begun at Cambridge University two years ago. Besides this a study of alpha-ray straggling and another on the ratio of gamma-rays to the number of the disintegrating atoms from which they come are being undertaken by graduate students under Professor Kovarik's direction.

Dr. Ernest O. Lawrence, assistant professor of physics, and Dr. Jesse W. Beams are engaged in a series of researches into the times necessary for the appearance and disappearance of the effects of electric and magnetic fields upon the transmission of light. An idea of the precision possible can be gained by considering that changing the position of either cell by only a few centimeters along the ray of light, corresponding to a time difference of much less than a billionth of a second, produces an observable change in the transmitted light.

The new interest of chemists in the use of physical methods in attacking their special problems is shown by the fact that two of the spectroscopic problems under way in the Sloane Laboratory are being conducted by Dr. I. W. M. A. Black, Commonwealth fellow in the department of chemistry. The band spectra of certain organic compounds will, it is hoped, permit them to decide between various structures of the molecule which are equally probable in the

EDWARD BRADFORD TITCHENER

FROM 1891 UNTIL HIS DEATH PROFESSOR OF PSYCHOLOGY IN CORNELL UNIVERSITY, WHERE HE REPRESENTED THE BEST TRADITIONS OF THE ENGLISH AND GERMAN UNIVERSITIES. THE PORTRAIT IS FROM A PAINTING BY OLAF M. BRAUNER, PHOTOGRAPHED BY J. P. TROY

light of chemical evidence alone. This work and other spectroscopic problems are directed by Professor Horace S. Uhler. Dr. Lee Kinsey, who holds a National Research Council fellowship in physics, is also working with Professor Uhler on optical problems, particularly on the reemission of light from metal vapors under intense illumination.

Professor John Zeleny has just completed experiments on the striated electric discharges in gases. At moderately low pressures and under certain ranges of applied voltage the passage of the electric current through a gas in a long straight glass tube is rendered visible by the appearance at regular intervals along the tube of transverse layers of luminosity separated nearly by dark regions. Dr. Frank L. Cooper has also been measuring potential differences in a gas carrying an electric current. There is a spontaneous potential gradient in the atmosphere of such a kind that a small positive current is almost always flowing down from inaccessible heights to the earth's surface. The atmospheric potential gradient has sudden fluctuations of such magnitude that it may even change sign, and these changes, if enough of them can be correlated with changes in local, terrestrial or solar conditions, should give a clue as to the origin of the potential gradient.

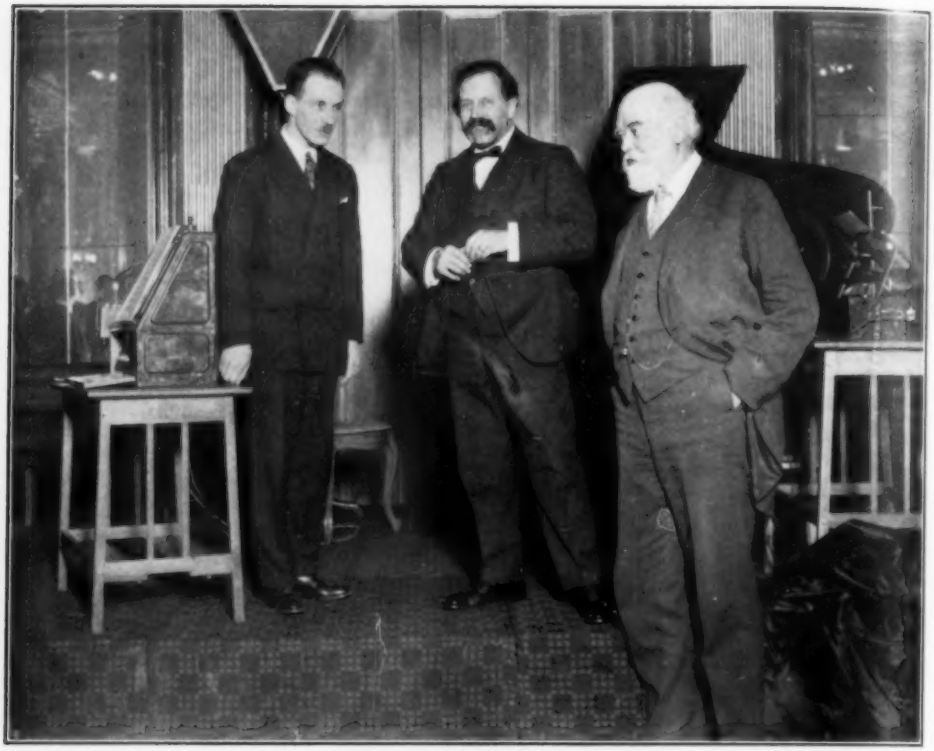
Another almost cosmical problem has been attacked by Dr. Norman I. Adams, Jr., assistant professor of physics. The local broadcasting station found its reception interfered with by a distant station assigned to the same frequency band. The trouble was that the two frequencies actually used would differ by a frequency within the audible range and control is feasible.

Precision measurement of x-ray wavelengths, involving as it does the elimination of experimental errors, demands a very high order of technical ability. Dr. Charlton D. Cooksey, assistant professor of physics, and his brother, Donald Cooksey, have devised and constructed instruments of the necessary refinement.

Among the other members of the faculty who are engaged in experimental researches are George W. Gardiner, Jr., who is investigating the proportion of absorbed radiation which reappears in the energy of photo-electrons, and Joseph E. Henderson, who is trying to fix the angles at which soft x-rays of long wave-length suffer total reflection from various metals. This total reflection is one of the most interesting facts recently discovered about x-rays. Preliminary work on the critical angles for reflection was done two years ago by Professor Elizabeth Laird, of Mount Holyoke College, as a visitor in the Sloane Laboratory.

MUSIC FROM THE ETHER

Professor Leon Theremin, of the State Institute for Applied Physics at Leningrad, is exhibiting in the United States his remarkable apparatus and methods of producing music by manipulating electric waves. According to an article printed in the London *Times*, when an exhibition was given in the Albert Hall, London, in December, the apparatus may fairly claim to be a new musical instrument, unlike the other wonderful inventions which have in recent years impinged upon the art of music. It is a source of sound, not a medium of transmission or reproduction. It has in it, therefore, possibilities which the gramophone and wireless broadcasting can not claim. It is, however, as Sir Oliver Lodge pointed out, not a miraculously new thing, but a development of principles which are already understood and utilized in wireless.



PROFESSOR THEREMIN

WITH HIS NEW MUSICAL INSTRUMENT. ON THE RIGHT IS SIR OLIVER LODGE, THE EMINENT PHYSICIST, AND IN THE CENTER SIR HENRY WOOD, THE DISTINGUISHED MUSICIAN.

It is known that the frequency of a thermionic valve oscillator can be varied by moving the position of an earthed conductor in the vicinity of the set. Broadcast listeners are familiar with the howl which proceeds from a loud-speaker of a set adjusted with too strong reaction. In such a case the frequency of the note emitted by the loud-speaker is equal to the difference in the frequencies of the transmitting station and the locally generated oscillations in the receiver. In badly designed sets this howl can be made to vary in pitch by moving the hand in the vicinity of the tuning condenser. Since the human body is earthed the hand acts like a condenser plate, so that moving it is equivalent to changing the tuning condenser.

In Professor Theremin's apparatus the musical beats caused by two high-frequency oscillations of neighboring frequencies are controlled by this hand-capacity effect, the pitch being increased when the operator's right hand is made to approach a vertical metal rod connected to one of the oscillating circuits. The fact that the note increases in pitch as the hand nears the rod seems to give the explanation of the way in which the oscillators are so easily controlled. It was discovered some years ago that two high-frequency oscillators could be locked or synchronized so as to maintain identical frequencies and so give no beat notes. Professor Theremin appears to start with his oscillators in this condition, for there is no audible note produced by his apparatus until his

right hand reaches a certain critical distance from the rod. When this critical distance is reached the two oscillators break step, as it were, and a beat note is produced which increases in frequency as the hand is pushed nearer the rod and the two sets put farther out of tune.

The control of the loudness of the emitted note is also carried out by a similar hand-capacity effect, but here the application of oscillating valve principles is not so clear. There are various ways in which it could be done, the most simple being an alteration of phase between two component oscillations of approximately the same amplitude. When the oscillations were in-phase a loud note would be produced, and when they were out-phase silence would result.

Professor Theremin thus describes his methods:

> By using an alternating current of suitable frequency tones of varying pitch are easily obtainable. A small vertical rod is used as the antenna. When the instrument is in operation electro-magnetic waves of very weak energy are generated around this rod. These waves are of a definite length and frequency. The approach of a hand, which is an electrical conductor, alters the conditions in the electro-magnetic field surrounding the antenna, changes its capacity and thus affects the frequency of the alternating current generated by the apparatus. In this manner a kind of invisible touch is produced in the space surrounding the antenna, and, as in a cello, a finger pressing on a string produces a higher pitch as it approaches the bridge, in this case also, the pitch increases as the finger is brought nearer the antenna.
>
> Likewise the intensity of tone can also easily be changed by a simple movement of the hand in space. For this purpose the instrument is equipped with another, in this case circular, antenna around which electro-magnetic waves are similarly formed. The approach of a hand toward this antenna causes a change in the oscillating circuit. This change is necessary in order to effect in the instrument a change in the degree of the intensity of the alternating current which produces the tone. Thus by raising the hand over the ring shaped antenna the note sounded grows louder and by lowering the hand it grows softer, until it dies out in the softest pianissimo.

THE SCHOOL SERVICE BUILDING OF THE AMERICAN MUSEUM OF NATURAL HISTORY

THE American Museum of Natural History dedicated on the evening of January 17 the School Service building, a four-story addition to the museum, in which the educational program will be conducted in the future. About 400 educators and public men witnessed the dedication and the unveiling of a memorial statue of William Henry Maxwell, New York City superintendent of schools from 1898 to 1918.

The transfer of the School Service Building, as a gift of the city to the museum, was made by Walter R. Herrick, president of the park board, representing Mayor Walker. In accepting it for the museum, President Henry F. Osborn said that in no other city in the world was there any building comparable to this new school. He said the trustees and officers would do everything they could to give every school boy and school girl in the city the advantages such an institution affords.

The tribute to the late Superintendent Maxwell was the central feature of the evening's program. After a speech of presentation in which he characterized Mr. Maxwell as "a great administrator and inspired teacher of teachers," John Greene, president of the William Henry Maxwell Association, offered the statue to the museum.

All the lights were put out, and in the darkness a curtain which had veiled the statue, standing against the rear wall of the hall, was drawn aside. Then lights were thrown on the statue, revealing an impressive, seated figure of Maxwell of heroic size, cast in green bronze. He is represented sitting in flowing academical robes, on a massive throne.

"Although he did not teach, he had the parts of a teacher," said Dr. John

SIR ERNEST RUTHERFORD AND LORD HALDANE

PHOTOGRAPH TAKEN ON THE OCCASION OF THE OPENING OF THE LABORATORY OF PHYSICS OF THE UNIVERSITY OF BRISTOL. SIR ERNEST RUTHERFORD (WHO IS ON THE LEFT), CAVENDISH PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CAMBRIDGE, AND LORD HALDANE, CHANCELLOR OF THE UNIVERSITY OF BRISTOL, MADE ADDRESSES AT THE DEDICATION OF THE LABORATORY, WHICH IS TO BE KNOWN AS THE H. H. WILLS PHYSICAL LABORATORY, THE GIFT OF MR. HENRY HERBERT WILLS, OF BRISTOL. [From a photograph supplied by the University of Bristol.]

H. Finley, formerly New York commissioner of education, in describing the career and life work of Maxwell. "He knew good teachers when he saw them. He was a terror to others. He was essentially an administrator. He would have made a great governor or railroad president or engineer or president of a trust company.

"As it was, he was head of the greatest trust company in the world with a million parent depositors yearly and with assets, beyond all estimates, in the potentialities of from half a million to a million children. What a godsend it was that the young Scotch-Irish scholar had the fortunes of a half million of such millionaires in trust rather than the millions of dollars of the ordinary money millionaire!"

Other speakers were Dr. John J. Tigert, United States commissioner of education, who spoke on "Museums as National Assets"; Dr. William J. O'Shea, superintendent of New York City schools, who discussed "The Museum and the City Schools," and George H. Sherwood, director of the museum, who gave a lecture with motion pictures on "The American Museum's School Service."

Visitors inspected the new building at the close of the program. It consists of a basement and four floors, 160 feet by 90 feet on the first floor and 55 feet wide on the upper floor. The first floor contains an education hall, reserved for temporary exhibits. The second floor has a reception floor for classes visiting the museum. On the third floor are administrative offices, study rooms, library and activities connected with the extramural work of the museum. The fourth is the production floor, where photographs and negatives are cared for and the photographic studios are located.

To the minds of the authorities of the American Museum of Natural History, nature work is of primary importance in education. Every year sees the educational program of the museum enlarged and to-day that institution is happily designated as "The Biggest Schoolhouse in the World."

The program of school service has the hearty endorsement of the Board of Education, superintendents and other school officials, but the conduct of the work is left entirely to the department of education of the museum, which is responsible for the institution's work with the schools. This action on the part of the school authorities has been an important factor in the success of the work because it has simplified it and brought the staff into direct touch with the teachers, which leads to a better understanding of our students' needs.

THE PHILADELPHIA COLLEGE OF PHARMACY AND SCIENCE

PHILADELPHIA'S latest addition to the city's many institutions of learning, the new building for the Philadelphia College of Pharmacy and Science, has been completed and was occupied the first week in January.

The new college building is located at Forty-third Street and Kingsessing Avenue, not far from the University of Pennsylvania, and presents many unusual features not to be found in other educational structures.

The site is in one of the most charming locations in West Philadelphia, and convenient to the central part of the city by numerous trolley lines which pass within a square of the building. The building itself occupies the most commanding portion of the large tract around the college, and on one side faces a large city park. This park itself provides a beautiful setting for the college building, and in addition offers unusual recreational facilities for the students.

The architectural style of the building is colonial of the Georgian type. It is

constructed of reinforced concrete, faced with dark red brick laid in Flemish bond and trimmed with buff Indiana limestone. On the Kingsessing Avenue, or main front, the structure is three stories in height, while on the Forty-third Street side, the building is four stories high. On all four sides, unobstructed daylight for the class rooms and laboratories is always assured.

The main entrance is characterized by the use of a triple arched doorway formed with columns and pilasters, supporting a massive pediment on which is carved the college seal. Entrance gates of hand forged iron are used, ornamented with disks symbolic of the various branches of instruction—pharmacy, botany, science, chemistry, literature and mathematics. The walls of the vestibule and lobby are faced with limestone and marble, and the floors are Terraza and rubberstone tile. The main stairs are of marble, supported on metal risers. All the interior walls of the corridors and passageways are finished with a traventine wall treatment.

One of the unusual features of the building is that it is built entirely above ground, with no basement rooms. By reason of the angular form of the structure, it was possible to provide daylight in every room without resorting to light courts or light wells.

Throughout the building special consideration has been given to the question of accoustics The ceilings of the laboratories, class rooms and recitation rooms are covered with one half inch thick insulite wall board. This material was installed during the period of construction by putting it on the wood forms before the concrete was poured. As a result, excess reverberation has been eliminated, making it possible to use all the laboratories for lecture purposes. Sound transmission between rooms has been removed by the use of tile and the omission of communicating doors. To further put a stop to any noises which would affect classes, the corridors have been faced with a soft flooring material which excludes any noises made by the movement of bodies of students passing in the corridors.

To provide facilities for an assembly of twelve hundred students without unduly enlarging the building, an arrangement has been developed whereby three large lecture halls and the gymnasium are grouped together. These three lecture halls, seating three hundred each, with their tiered seats, face in an angular fashion the floor of the gymnasium, and by an arrangement of mechanically operated curtains, the halls may be thrown into one large hall, forming an amphitheater type of auditorium. Norman Hulme, R.A., of Philadelphia, was the architect.